

AD-A186 984 AN EXPERT SYSTEM FOR ASSET RECONCILIATION(U) AIR FORCE  
INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYSTEMS  
AND LOGISTICS 5 A MCCAIN SEP 87 AFIT/GLN/LSV/875-46

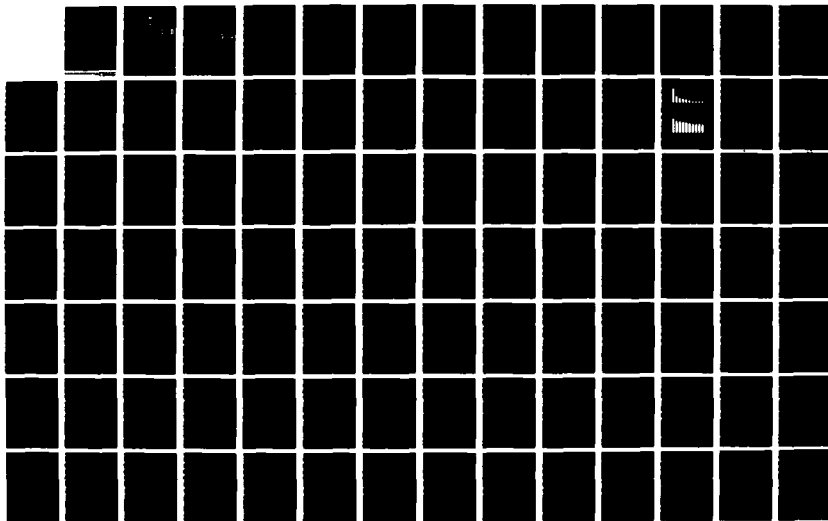
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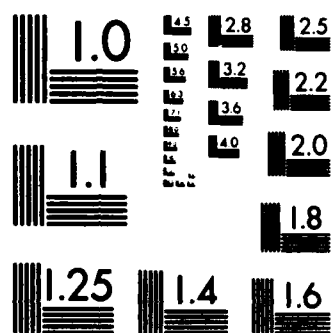
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THESIS

Steven A. McCain  
Captain, USAF

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AFIT/GLM/LSY/87S-46

AN EXPERT SYSTEM FOR ASSET RECONCILIATION

THESIS

Presented to the Faculty of the School of Systems and Logistics  
of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the  
Requirements for the Degree of  
Master of Science in Logistics Management

Steven A. McCain, B.S., M.B.A.

Captain, USAF

September 1987

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Captain Steven A. McCain

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Abstract

Expert system technology appears to hold considerable promise for enhancing productivity and promoting better decision-making. The purpose of this study was to determine if an expert system application for asset reconciliation could improve inventory management procedures and potentially produce savings for the Government while alleviating manpower shortages.

The primary objective of this research was to validate and extend a previous research finding that documented a 15 percent increase in the effectiveness of inventory managers when assisted by an expert system. Research was conducted to develop an expert system for a different task and to measure the performance level of this expert system, both in terms of the effectiveness and the efficiency of item managers who were assisted by the system.

The methodological approach to the research effort involved a twelve-step process that was divided into three general phases. The objective of the first phase, problem selection, was to choose a problem to be addressed by the expert system and to select the domain experts whose knowledge would be encoded into the expert system to solve the chosen problem. The objective of the second phase, knowledge engineering, was to extract the knowledge from the

selected experts in order to create a knowledge base for the expert system. The objective of the final phase, performance evaluation, was to determine if the developed expert system enhanced or detracted from the productivity of inventory managers using the system.

The expert system developed was titled the Manager's Asset Reconciliation System (MARS). MARS improved the overall effectiveness of item managers, who used the system to complete test cases, by 19.45 percent. There appeared to be a reduction in the efficiency of item managers assisted by the expert system. The lack of user familiarity with computer operations and MARS was assumed to contribute to this reduction. This study also provides suggestions for modifications to MARS that will improve the expert system consultation thereby increasing the efficiency of the system. User acceptance of MARS was high and recommendations for further testing of MARS are provided.

# An Expert System for Asset Reconciliation

## I. Introduction

### Overview

The technology of Artificial Intelligence (AI), specifically expert systems, appears to have considerable capability for enhancing productivity and promoting better decision-making. The technology has emerged from the research laboratory demonstrating successful applications for a wide range of business operations. A 1986 article in Dun's Business Month, "Computers Think for Business," states:

Companies in virtually every industry are using expert systems and making major efforts to disseminate the technology throughout their organizations. Close to 100 custom-built systems and more than 1000 off-the-shelf systems are now in operation [21:30].

The potential power of expert systems to replicate rare or expensive human expertise has led to a worldwide effort to extend and apply this technology [51:viii]. Harmon and King note in their book Expert Systems: Artificial Intelligence for Business:

Today, the United States, Japan, England, and the European Economic Community are all in the process of launching major research programs to develop and implement expert systems in the near future [23:1].

The Air Force Logistics Command (AFLC) has recognized the potential of AI and has developed a strategy for applying expert system technology to the command's maintenance, acquisition, requirements, and distribution activities. Expanding workloads, serious shortages in expertise, and 'belt tightening' budgets make such a strategy crucial to needed improvements in productivity. To quote the CORONA REQUIRE study which was chaired by General Alton D. Slay, USAF (Retired) and presented to the Chief of Staff and the Secretary of the Air Force in 1983:

Given the non-responsive Automated Data Processing (ADP), there are insufficient numbers of Item Management/Equipment Management and Contracting Specialists. Manning levels for each have dropped from around 90% to the 70-75% range in the last two years while the workload has almost doubled. Further, the skill level, particularly of the Item Management Specialists, is a serious problem as rapid turnover has drained the experience base [43:7].

Until recently, Air Force AI applications primarily addressed the problems of battle management, design engineering, and the cockpit environment, with relatively little emphasis on the area of inventory management. Expert systems, however, offer tremendous potential for improving the management of inventory [3:24]. Poor inventory management wastes valued resources. AFLC capital assets equalled \$115.7 billion as of March 1987 [15:2-39]. In addition, the Command bought, stored, issued and distributed 929,700 items in fiscal year 1986 [14:ii]. Even a small improvement in



the management of these items suggests significant savings could be realized by AFLC and the Federal Government.

The objective of this research was to validate a previous research finding that documented a 15% increase in the effectiveness of inventory managers when assisted by an expert system. Further, the research discussed herein extended the previous study to an additional area of inventory management, specifically, the area of asset reconciliation. Background information on expert systems is provided next so the reader may better understand the proposed research which was conducted. Basic expert system terminology is defined in Appendix A.

#### Background

Expert Systems are computer software programs that emulate limited aspects of human thinking. An expert system can be defined as, "any system that can process data and deliver or administer the advice or expertise a human expert would give under the same circumstances [38:58]."

Expert systems execute chains of logical reasoning linking facts and conclusions by incorporating human knowledge and experience [32:35]. Expert systems use search heuristics, described as "procedures, strategies, and rules of thumb for problem solving [51:5]," to reduce the size of the problem space and to arrive at a solution. The human expert's heuristics are loaded into the expert system's "knowledge base" as rules and facts about the area or domain

of interest from which decisions can be derived.

The most common method used to represent knowledge in contemporary AI applications is the rule-based method [41:93]. Knowledge is represented as "a collection of individual situation-action rules, each one of which captures a single inference, action, or contingency for a particular class of situations [41:93]." An example of a rule for a medical diagnosis expert system might be represented as follows:

```
      if  the patient's blood pressure is dropping
        and there is no internal injury
      then suspect internal bleeding [41:93]."
```

The term "expert" is described by Paul E. Johnson, a behavioral scientist, in the following quote:

```
      A person who, because of training and experience,
      is able to do things the rest of us cannot;
      experts are not only proficient but also smooth
      and efficient in the actions they take. Experts
      know a great many things and have tricks and
      caveats for applying what they know to problems
      and tasks [51:5].
```

The inference engine, the system's data manager and query processor, uses a search strategy that directs the expert system to evaluate only those rules and facts that are applicable to the problem at hand. Each time the system is queried by the user a response is made by searching through the rules and facts in the system's knowledge base. If the system is unable to reach a conclusion based on present knowledge of the situation, the user is prompted to supply additional information. This information can be

added to other conclusions stored during the consultation with the expert system, thereby upgrading the system. The process continues until the system reaches a final conclusion and recommends a management action [10;47:3].

Figure 1 describes the basic structure of an expert system. The actual process of building an expert system is called knowledge engineering [51:5]. The building process is conducted by a knowledge engineer whose job involves determining what an expert does when making decisions and organizing this information into an effective expert system implementation [22:13]. Research has determined that domain practitioners, i.e. logisticians, make the best knowledge engineers for their domain [5:6]. Knowledge acquisition facilities are used to transfer the knowledge from the human expert or other information source into a form that can be used by the expert system [45:G-10]. The knowledge base contains information gleaned from the human expert by the knowledge engineer [25:10]. The inference system provides overall control of the system and acts as an explanation generator, supplying information to the user that describes how the expert system arrived at solutions [3:18-20].

Expert systems can be applied to the general classes of problem solving shown in Figure 2. Problems that involve the manipulation of large quantities of information using heuristics, pattern matching, and searching procedures are considered well suited for expert system application. The

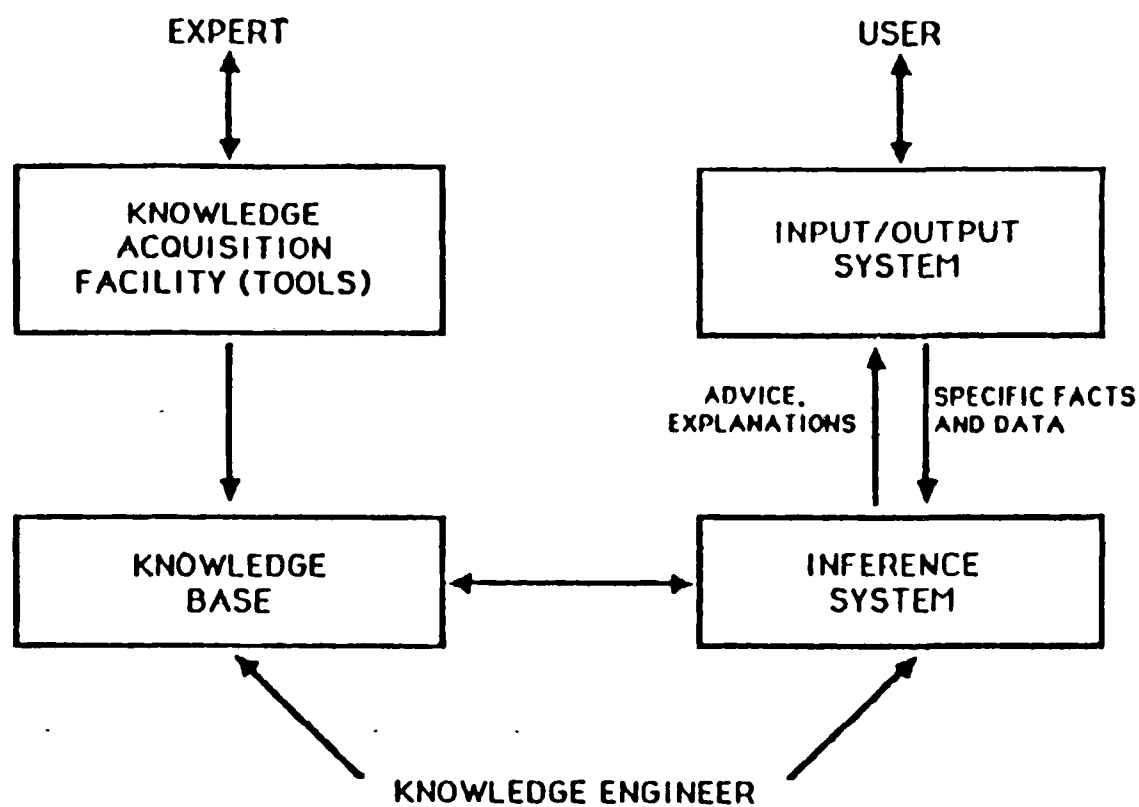


Figure 1

Basic Structure of an Expert System [18:76]

---

Interpretation	inferring situation descriptions from sensor data
Prediction	inferring likely consequences of given situations
Diagnosis	inferring system malfunctions from observables
Design	configuring objects under constraints
Planning	designing actions
Monitoring	comparing observations to plan vulnerabilities
Debugging	prescribing remedies for malfunction
Repair	executing a plan to administer a prescribed remedy
Instruction	diagnosing, debugging, and repairing student behavior
Control	interpreting, predicting, repairing, and monitoring systems

---

Figure 2

General Classes of Expert System Problem Solving [23:3]

development of any expert system requires the existence of a person who can already successfully solve the problem. Ideally this human expert is available and committed to the development of an expert system for the problem domain.

Problems which make good candidates for an expert system are those problems where knowledge and experience have a significant effect on the accuracy of the solution chosen [46:11]. If this knowledge is crucial, yet concentrated in just a few individuals, the development of an expert system is especially suitable for an organization. The completed system should offer a significant payoff for the using organization [37:26].

Expert systems are not well suited for problems that require the senses of taste, touch, sight, and smell [46:11-8]. A simple test to determine if the task or problem is dependent upon these senses for unambiguous communication is the "telephone test." If a human expert can help the intended user of the expert system solve the problem over the telephone then the problem is potentially suited for an expert system [44:11-8].

The problem task should be defined very clearly in order to focus the development of the expert system [33:27]. The problem should be limited to a narrow, specialized domain in order to keep the size of the required knowledge base manageable [3:66]. The selected task should be neither too easy so as to lack credible reasons for development of

an expert system nor too difficult to make the required assimilation and encoding of information into a knowledge base impractical [37:28].

If a problem cannot be solved using conventional programming, an expert system may offer a solution. Expert systems manipulate knowledge while conventional computer programs manipulate data [51:24]. Expert systems can offer solutions to problems that require heuristic, inferential processes as opposed to the algorithmic, repetitive processes of conventional computer programs [51:24].

Advantages. Expert systems offer some advantages over human experts [2:3]. Humans have difficulty dealing with the complexity of problems in today's work environment. Even when complex problems are broken down into subcomponents, being able to understand the impact of a decision on other areas of the system is extremely challenging. An expert system lends support to the decision-maker in complex problem solving activities. Expert systems can assimilate huge amounts of data and examine a large number of related factors simultaneously. Cost reductions are achieved as the time required to gather and process data is reduced. Constantly changing rules, procedures, and methodology are difficult for 'experts' to assimilate. Expert systems can quickly assimilate new information and apply the information to aid management in the decision-making process [47:197].

Expert systems are not biased by personality, emotion, or politics [2:3]. Expert systems do not forget key factors, as humans occasionally do under pressure. Such systems make consistent recommendations. Such a system would be available 365 days a year, 24 hours a day. "They don't get sick, go on leave, travel on business, transfer, or retire [2:3]." Further, the real experts in an organization are very busy and rarely have time to help a junior manager work through a time consuming problem.

Expert systems can automatically keep a historical record of all decisions for future use and analysis. The system often represents the first written record of the knowledge in the domain [3:20]. In developing an expert system, the organization's experts must closely examine the rules, policies, and data that are required to successfully accomplish the goals of the organization. This intensive scrutiny often results in the discovery of more efficient and effective ways of doing business [2:4]. Once the system is in place and being used, the human expert has more time to devote to innovation [2:4].

The training role is another functional area where expert systems can be applied advantageously. New personnel might feel uncomfortable asking the boss the same "stupid" questions over and over again. They do not mind, however, asking a "user friendly computer tutor" [2:4]. An expert system can answer the question, offer a solution, and also



explain the logic behind the proposed decision. The system's reasoning is easily modified if a flaw is detected. Expert systems are easily duplicated and copies can be distributed wherever the expertise is needed. Human experts must be trained and educated over long periods of time [2:3-4].

Figure 3 represents experience levels in a typical organization. The group with the most experience is represented by the tallest bars on the far left [2:5]. In most cases, these experts have been with the company for many years and are nearing retirement. The retirement of personnel with so much accumulated knowledge represents a serious loss of expertise to the organization. Additionally, a shortage of experts in the organization curtails profitability [23:197]. A knowledge engineer can change this situation by interviewing the experienced workers and encoding their acquired knowledge in an expert system. Under ideal conditions, the implementation of an effective expert system allows everyone, including the new employees, to work near the level of the expert as depicted in Figure 4 [2:5].

Disadvantages. Expert systems also have certain disadvantages. Expert systems are not applicable in every case. If forced upon an organization that is either unprepared or unwilling to properly apply an expert system, the potential for disruption of the existing organization is

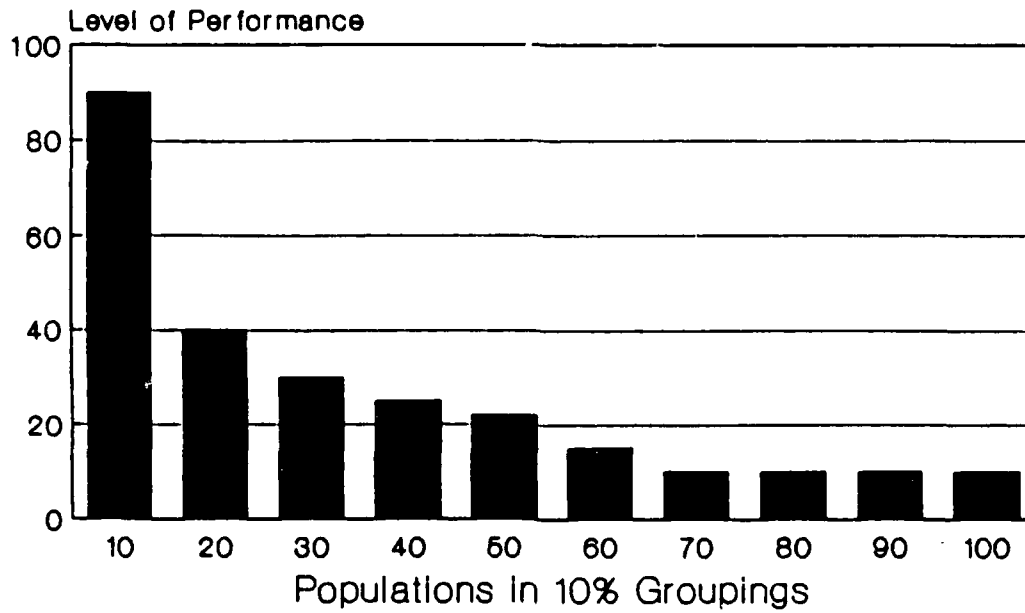


Figure 3

Performance of a Typical Organization [2:5]

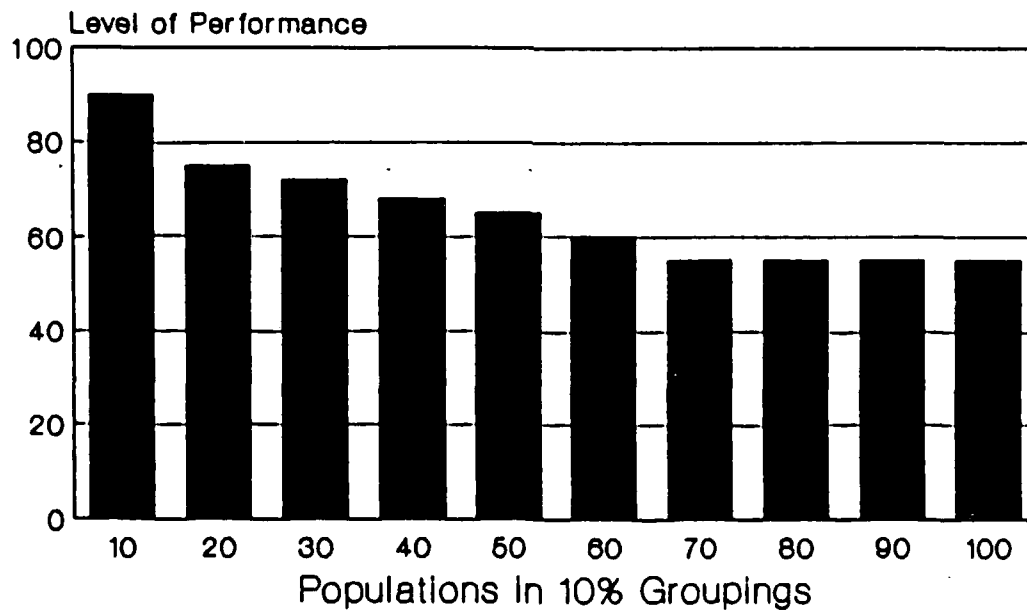


Figure 4

Level of Performance with an Expert System [2:5]

considerable [2:1]. Expert systems perform best for limited task situations. A complicated management task might therefore require several expert systems to fully address the situation [2:6].

Expert systems are very difficult to construct and can require a great deal of time and money for development and implementation [2:6]. Years of effort by high-priced knowledge engineers and domain experts can be required for some expert systems [51:13]. Many systems require specialized programming and expensive computer hardware [47:202].

'Extracting expertise from an expert is the most difficult aspect of creating an expert system [32:37].' Expert system development involves gleaning information from human experts who often do not know in explicit detail how they solve problems and tasks [2:6]. Knowledge engineering can be a slow and inexact process [3:73].

Expert systems also require constant updating and modification for the reasons indicated below:

1. Validation efforts frequently reveal faulty or inconsistent logic which must be corrected.
2. Systems are continually expanded to handle additional tasks.
3. Knowledge in the field evolves.
4. Policies and regulations change.
5. Better ways of performing the task are discovered [2:6].

The maintenance and upkeep of expert systems, especially for systems that use any of the more complex programming

languages, requires highly trained users and operators. Such trained personnel are currently a scarce resource in most organizations [47:201-202].

A major potential disadvantage, described by Mike Van Horn in his book Understanding Expert Systems, is the 'garbage in - gospel out' syndrome [47:6]. This syndrome basically describes the possibility that users would be afraid to override the system's recommendations. In my opinion, too great a dependency on any decision-making technology is not desirable.

Current rule-based expert systems can only make decisions regarding the specific rules and facts entered in the knowledge base of the system. Expert systems can only be used for the narrow task that the system was designed for [11:62]. Additionally, the required scoping of expert system problems can cause myopic judgements to be offered to the user of the system ignoring the broader problem implications [27:35].

Testing and evaluation of an expert system is very difficult [51:198]. A developed system often requires an extensive period of testing, validation and refinement before becoming a reliable tool [47:199]. The problems addressed by expert systems do not generally have clear cut right or wrong answers [3:84]. There may be no formal way to prove the answer given by the system is the best possible choice, making evaluation of the system difficult [51:198].

Trends. In solving problems, human experts rely on a combination of experience, insight, and intuition that no knowledge base can yet match [40:64]. Advances in natural language programs that simplify the interaction between the user and the computer will enhance the capabilities of future expert systems. Improved graphics, knowledge acquisition software, and information networks are making expert system technology an increasingly viable management tool [11:61]. The number of people trained in AI, including knowledge engineers and AI language programmers is rapidly rising [47:203-204]. Eugene Wang, Vice President of Gold Hill Computers states in a 1987 article for AI Expert:

Over two-thirds of Fortune 500 companies currently have AI projects staffed and under way. The total AI market is projected to grow from over \$1 billion in 1986 to over \$4 billion in 1990. Expert systems are projected to grow from \$145 million in 1986 to \$810 million in 1990 [49:6].

Finally, small computers are gaining more power and versatility. Small computers have greater memory capacity, and are less expensive than in the past. The increased capabilities of small computers, particularly microcomputers, will provide potential users with a low risk opportunity to bring expert system capabilities in-house, and, as a result, determine the probable value of this technology for their applications [31:207]. "Companies that do not develop expertise in tapping this technology within the next few years will be at a competitive disadvantage [49:6]." The trends described above will facilitate

the continued growth of expert systems application in industry and will increase the capacity of expert systems to enhance productivity [47:205].

The background information presented thus far was provided so the reader might better understand the research which was conducted. The basic structure and function of an expert system was discussed. Expert system advantages, disadvantages, and trends were also described.

#### Statement of the Problem

Research conducted by Dr. Mary K. Allen demonstrated that an expert system can enhance the decision quality of inventory managers regarding the D041 system. The D041 computes replenishment spares requirements for reparable items in AFLC. As a result of the success the Inventory Manager Assistant (IMA) expert system demonstrated, Dr. Allen suggested continued research on other inventory management tasks. Her research included a listing of 26 inventory management tasks that were considered by experts in the field of item management to have potential for expert system application. Asset reconciliation was ranked number 6 out of 26 potential tasks [3:112] and was selected for the research described herein.

Asset reconciliation is the process of comparing worldwide reported assets with the known asset position and making the two compatible. An asset reconciliation record, AFLC Form 47, is used for the computation. A sample of a

Form 47 is depicted in Figure 5. The asset reconciliation record must be maintained to provide an accurate record of assets in the system [50:1]. Failure to properly maintain these records can cause considerable cost increases through the improper buy, repair, termination and disposal of inventory items. Mission readiness is reduced when needed items are not procured or repaired because inaccurate records do not reflect the need. The efficiency of inventory management operations is reduced when time-consuming research is required to correct frequent item record inaccuracies.

This research was undertaken to validate Dr. Allen's study by developing an expert system for a different inventory management task and measuring the resultant change in productivity of item managers who were assisted by the developed expert system.

#### Research Questions

1. Is asset reconciliation a suitable problem for application of an expert system?
2. Can the knowledge needed to solve the selected problem be extracted from human experts?
3. Can the rules needed to perform an asset reconciliation be encoded using the Teknowledge M.1 software program?
4. How does the developed expert system prototype affect the productivity of the using organization?

ASSET RECONCILIATION-INVESTMENT ITEMS					
NATIONAL STOCK NUMBER	ITEM ACTIVITY CODE	AS OF DATE	AS OF DATE	AS OF DATE	AS OF DATE
1. TOTAL ACQUIRED ASSETS					
2. STARTING POSITION (Date:)					
3. ASSET LOSSES					
Condemnations					
Mock ups					
Installations/SPRAM					
On loan (Bailments)					
Test Equipment					
Shipments to FMS/SA Programs					
Shipments to Non Reporting Activities					
Special Projects					
Modification					
Minus IAV					
Transfers to R&M					
Other (Explain in Remarks)					
TOTAL (ASSET LOSSES)					
4. ASSET GAINS					
Plus IAV					
Modification					
Other (Explain in Remarks)					
TOTAL (ASSET GAINS)					
5. BALANCE ACCOUNTABLE ASSETS					
6. DUE IN ASSETS:					
On order PR/MPR (Funded)					
On order contract					
Unfunded PR (Information Entry)					
ISSP					
Reclamation					
Contract Termination					
Other (Explain in Remarks)					
TOTAL (DUE IN ASSETS)					
7. NET BALANCE ACCOUNTABLE					
8. CURRENT SB & CR ASSETS					
Serviceable (Include DIRM)					
Unserviceable					
Intransit (Serviceable)					
Intransit (Unserviceable)					
WRM (Serviceable)					
DION					
Other					
TOTAL (CURRENT SB & CR ASSETS)					
9. DIRM (Included in Block 8)					
10. NET SB & CR ASSETS (Block 8 Block 9)					
11. DIFFERENCE (Block 7 vs Block 10)					
12. ADJUSTMENT TO REPORTED ASSETS AFTER RESEARCH					
13. NET DIFFERENCE (BLOCK 11 + / - BLOCK 12)					
14. PERCENTAGE OF NET DIFFERENCE (BLOCK 13 ÷ BLOCK 7)					
15. ON HAND ASSETS USED IN COMPUTATION					
16. REMARKS (Continue on reverse)					

AFLC FORM 47  
OCT 82

PREVIOUS EDITION IS OBSOLETE

Figure 5

AFLC Form 47 used for Asset Reconciliation [47:Atch 1]



- a. Does use of the expert system increase effectiveness by at least 15%?
- b. Does use of the expert system reduce the time required by the item manager to complete an asset reconciliation?
- c. What is the user's subjective evaluation of the assistance provided by the expert system for asset reconciliation computations?

5. How significant is experience level in determining performance level when assisted by the expert system? Does use of the expert system help less experienced item managers more than experienced item managers?

#### Scope of the Study

The research effort was limited to the Warner Robins Air Logistics Center (WR-ALC), Directorate of Materiel Management (MM), Robins Air Force Base, Georgia. WR-ALC was chosen because the Director of Materiel Management expressed interest in the project and promised the cooperation and availability of needed personnel and resources. Research was limited to the Robins AFB site due to time constraints of the Graduate Program curricula of the Air Force Institute of Technology.

The selected problem task was bounded to include only the asset reconciliation computation of D041 items using AFLC Form 47. Expert systems are best suited to narrowly scoped problem tasks as discussed earlier in this chapter.

#### Limitations

The expert system software development package was preselected. The selected package, M.1 by Teknowledge, is a

rule-based system that uses 'backward chaining.' Backward chaining is a reasoning process that works backwards from the desired solution to find facts that support the solution [29:34]. Knowledge base rules are linked or 'chained' together [47:108]. The backward chaining reasoning process may not be the best means of representing inventory management knowledge; therefore, preselection of the M.I knowledge acquisition package was a limitation.

A second limitation concerned the level of test subject familiarity with computers and expert systems. Individuals selected to complete an asset reconciliation test case using the expert system were only given a five to ten minute introduction explaining how to use an expert system prior to the measurement of their actual test performance and their time to completion.

A third limitation involved the restriction upon available Temporary Duty time imposed by the requirements of the Graduate Program curricula of the Air Force Institute of Technology. The depth of knowledge engineering and performance testing was reduced by this constraint.

#### Assumptions

The researcher made the following assumptions:

1. The research conducted at Sacramento ALC listing 26 potential inventory management tasks for expert system application is applicable to Warner Robins ALC.

2. The results of the present research regarding the development of an asset reconciliation expert system is applicable to all the Air Logistics Centers despite being conducted solely at WR-ALC.

#### Contributions of the Research

The improved management of inventory resulting from expert systems application could be transformed into huge savings [3:181]. AFLC alone has responsibility for management of resources valued in excess of 50 billion dollars [1:1]. The estimated total U.S. commercial logistics expenditures for inventory carrying cost for 1982 were listed as 130 billion [3:24]. These figures suggest even a small percentage improvement in resource management could yield huge savings.

Development of an expert system for the asset reconciliation task appears to have the potential to alleviate critical manpower shortages by increasing the efficiency of inventory manager activities. Training capabilities will also be enhanced by the development of an expert system for asset reconciliation.

The research also expanded the information base regarding the development of expert systems for inventory management. The new information can be used for follow-on studies thereby enhancing the development of expert system technology in the Department of Defense.

### Organization of the Research Report

This chapter provided background information on expert systems, stated the problem, listed research questions and discussed the scope of the research. Chapter I also summarized the limitations, assumptions, and contributions of the research. Chapter II reviews the relevant literature regarding expert system applications and the measurement of expert system performance. Chapter III explains the methodology followed in the conduct of this research. Chapter IV presents the findings and analyses. Chapter V offers conclusions and recommendations.

## II. Literature Review

### Overview

The purpose of this chapter is to review the literature in order to provide a better understanding of the issues related to the development and performance measurement of an expert system. This chapter consists of three sections. The first section reviews the problem selection phase of expert system development. The second section discusses expert system performance evaluation issues and validation criteria. The final section describes actual expert system applications and their associated performance in terms of efficiency, effectiveness, or a combination of both efficiency and effectiveness.

### Problem Selection

This section will first review problem selection issues and then discuss the problem selection methodology used for the conduct of the prior research being validated.

Problem Selection Issues. Problem identification for the expert system application is crucial to the success of the developmental effort [3:55]. Initial problem assessment consists of the following activities:

- Identify problem domain and task
- Judge appropriateness
- Consider economic justifications
- Identify experts and the nature of their advice

- Identify the users of advice
- Identify sample cases [3:56]."

Figure 6 lists criteria for potential expert system tasks.

- 
1. Choose a task that someone performs competently.
  2. Good domains and tasks are knowledge-intensive. Experience has sizeable effect on the solution.
  3. Facts are accessible and generally understood by typical users.
  4. Facts remain stable for the duration of a consultation.
  5. Solutions can be enumerated.
  6. Entities in the domain are discrete.
  7. One single-instance entity is clearly at the heart of the task.
  8. The task passes the 'telephone test.'
- 

Figure 6

Task Selection Criteria [46:11-5 thru 11-9]

Expert system problem selection criteria can be separated into three main groups: possible, justified, and appropriate [51:127]. Figure 7 summarizes the problem domain characteristics that make expert system development possible. Figure 8 summarizes the problem domain characteristics that make development of an expert system justified. Figure 9 illustrates the problem domain characteristics that make the use of an expert system appropriate.

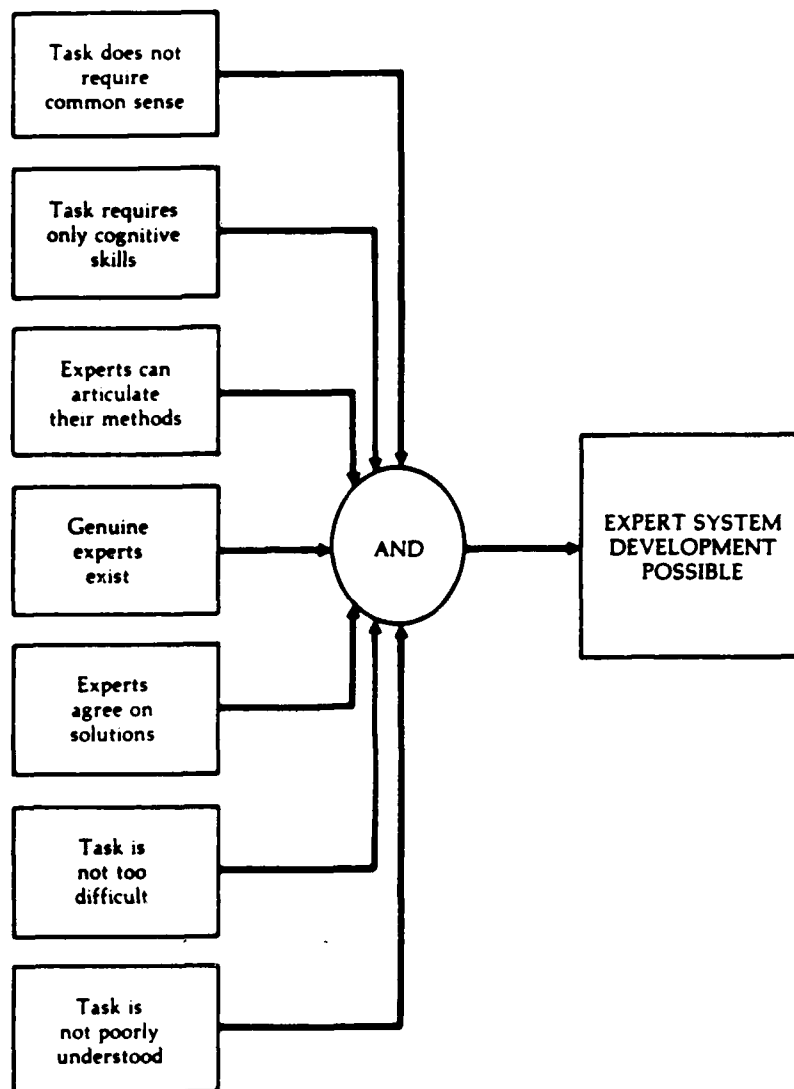
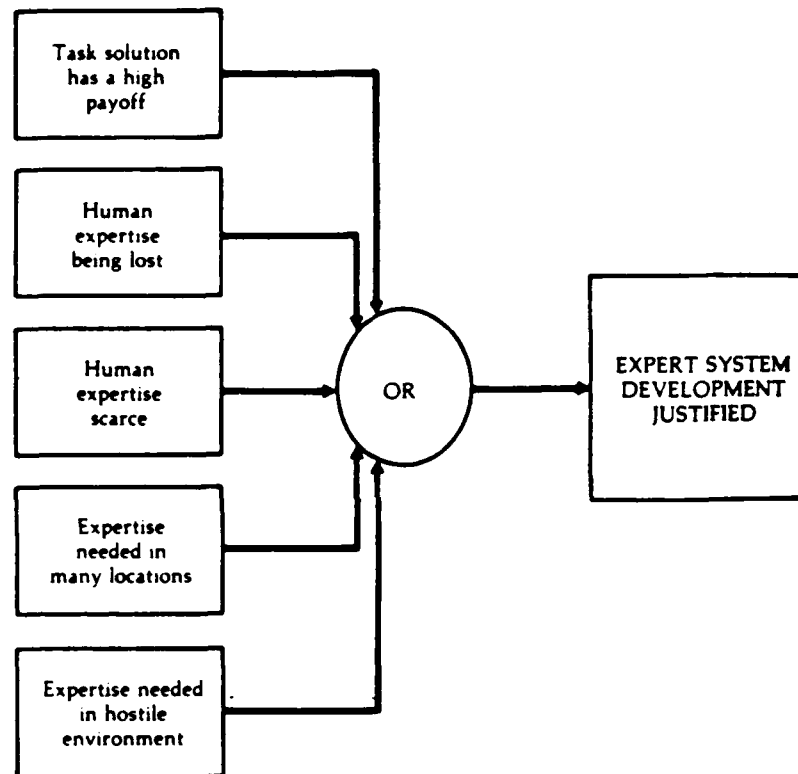


Figure 7

Necessary Requirements for Expert System Development [51:129]



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Figure 8  
Justification for Expert System Development [51:130]



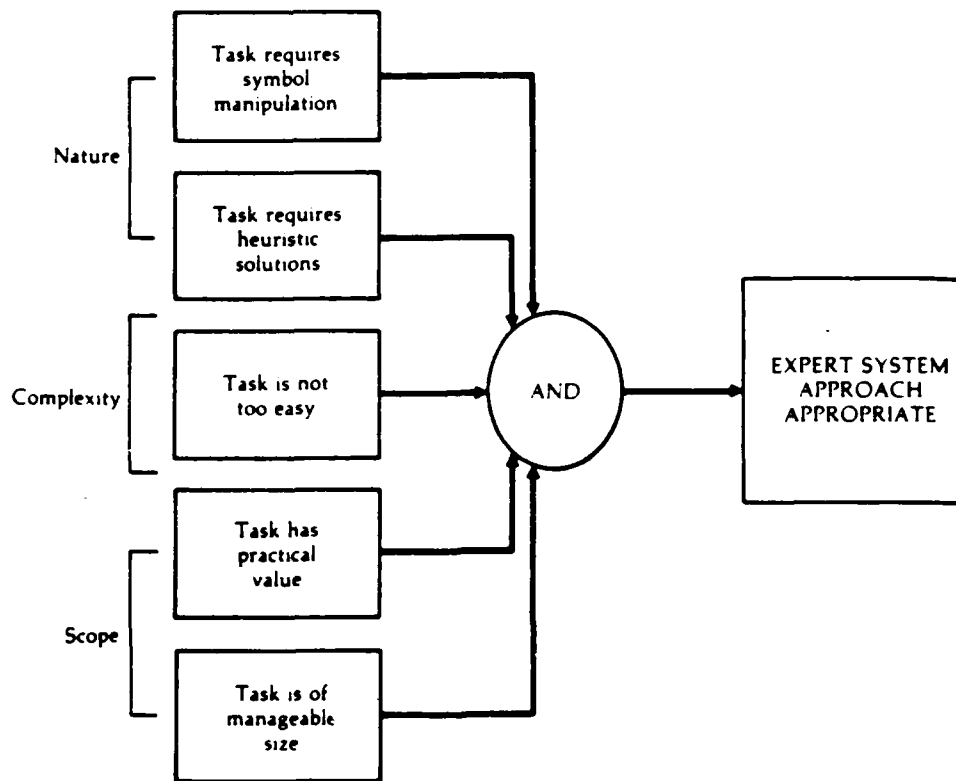


Figure 9

Characteristics that Make the Use of  
Expert Systems Appropriate [51:132]

One of the most important problem selection criteria is the existence of a qualified expert [51:128]. Another key criteria according to Sandra Cook, vice-president of expert systems at MAD Intelligent Systems, is that expert systems "should be used for problems that can be satisfactorily solved by human experts at such a high level that somewhat inferior performance is still acceptable [17:90]." Problems should require satisfactory versus optimal solutions [3:67].

Problem Selection Methodology. This subsection summarizes the methodology, used by Dr. Allen in 1986, to select an appropriate problem for expert system development. Dr. Allen's objectives during the problem selection phase of her research entailed the completion of the following steps:

- Step 1 - Domain Familiarization
- Step 2 - Domain Analysis
- Step 3 - Expert System Workshop
- Step 4 - Task Selection
- Step 5 - Expert Selection [3:98]."

The objective of Step 1 was to gain familiarity with an item manager's tasks and basic vocabulary. Step 2 provided a broader understanding of the item manager's work environment. During Steps 3 and 4 the expert system applications list was developed from which the asset reconciliation task was chosen. Step 5 involved the selection of experts whose knowledge was encoded in the expert system developed [3:98-115].

An expert system workshop conducted at Sacramento ALC comprised Step 3. The workshop was designed to prepare selected item managers to recommend candidate problems for expert system application. The workshop lasted three hours and was attended by a total of ninety item managers. The workshop session consisted of three blocks of instruction. The first block described what expert systems are, advantages, uses, examples of existing systems, and steps in the development of an expert system. The second block presented specific selection criteria for problems well suited to expert system application. The third block was used as a brainstorming session. Item managers were asked to suggest candidate expert system applications [3:106-108].

Item managers were also encouraged to submit candidate applications on three-by-five index cards. Each item manager was asked to submit a preferred candidate task application with a brief description of the advice an expert system developed for this task would provide. Twenty-six potential tasks were recommended by the item managers [3:108]. A modified Delphi Technique was used for Step 4, Task Selection. The Delphi Technique

is a method for the systematic solicitation and collation of judgements on a particular topic through a set of carefully designed sequential questionnaires interspersed with summarized information and feedback of opinions derived from earlier responses [14:10].

Each of the item managers who attended the workshop was given a Delphi ballot which listed each of the twenty-six

recommended applications. The item managers were asked to select and rank their five most preferred applications, with number one representing the most preferred alternative [3:109].

Eighty-six item managers completed the Delphi ballots. The rankings were weighted as follows:

<u>Priority</u>	<u>Weight</u>
1	5 points
2	4 points
3	3 points
4	2 point
5	1 point [3:111]

The total weighted scores for the eighty-six item managers are listed in Table 1.

Project applications receiving total weighted scores greater than fifty points were chosen for a second task selection questionnaire. Seventy-eight item managers reviewed the seven projects that met or exceeded the fifty point minimum total weighted score. The item managers then rank ordered their top three choices using the following weighting criteria:

<u>Priority</u>	<u>Weight</u>
1	3 points
2	2 points
3	1 point [3:113]

The total weighted scores are indicated in Table 2. 'Scrubbing the D041 computation' received the highest ranking and was selected as the task for which Dr. Allen developed the Inventory Manager Assistant expert system in 1986 [3:113].

Table 1

Total Weighted Project Scores, First Questionnaire [3:112]

---

<u>Project</u>	<u>Total Weighted Score</u>
1. Excesses	10
2. Allocation Decisions	13
3. Item Analysis	39
4. Controlled Exceptions	97
5. Backorder Listing	47
6. Repair Requirements	128
7. Cataloging Action	19
8. MICAP Support	18
9. Computer Products	48
10. Initial Provisioning	35
11. PR's	31
12. FMS Support	17
13. S06's (Budget)	148
14. Critical Item Advisor	44
15. Project Focus	8
16. Shipment Advisor	13
17. Asset Reconciliation	83
18. Fill Rate Advisor	15
19. Scrubbing D041 Computation	207
20. General Training	66
21. D041 File Maintenance	109
22. Special Levels	19
23. Amended Shipping Instructions	5
24. PJJ/414	23
25. D032/J041 Reconciliation	36
26. Other Service Support	15

---

Table 2

Total Weighted Project Scores, Second Questionnaire [3:114]

---

<u>Project</u>	<u>Total Weighted Score</u>
General Training	36
Asset Reconciliation	37
Controlled Exceptions	40
D041 File Maintenance	54
Repair Requirements	94
S06's (Budget)	87
Scrubbing the D041 Computation	126

---

Asset reconciliation was ranked six out of the twenty-six potential applications. The asset reconciliation task was selected for expert system development for the research described in the present thesis.

#### Performance Evaluation

Limited information on the evaluation of expert is available in the literature. However, considerable literature exists regarding the systematic evaluation of information systems. The relationship between information system evaluation and expert system evaluation was considered to be

worth reviewing along with literature specifically related to expert system performance measurement.

When to Evaluate. Evaluation should be informal through the early stages of development and become increasingly formal as the system moves toward real-world implementation [42:576]. Once an expert system prototype is functioning well for most of the cases presented, a more formal evaluation of the system is appropriate [3:83]. Table 3 represents a chronological progression from the less formal to the more formal stages of testing [42:577].

During Step 1 of a system's development, explicit statements which define the measures of the program's success and the methods of evaluating failure or success are required. The goal of Step 2 is to demonstrate that there is an appropriate knowledge representation scheme for the task domain. The appropriateness of the knowledge representation scheme is demonstrated by the successful handling of a few test cases that suggest a high-performance expert system is possible. Step 3 involves informal testing which seeks to define major problem areas in the system and to guide the iterative process of system development [42:577].

Step 4 involves the assessment of the program's actual utility in a potential user environment and consists of a more structured evaluation of performance. A formally randomized test scenario is developed to show the system is

Table 3

Steps in the Implementation of an Expert System [42:577]

---

1. Top-level design with definition of long-range goals
  2. First version prototype, showing feasibility
  3. System refinement in which informal test cases are run to generate feedback from the expert and users
  4. Structured evaluation of performance
  5. Structured evaluation of acceptability to users
  6. Service functioning for extended period in prototype environment
  7. Follow-up studies to demonstrate the system's large-scale usefulness
  8. Program changes to allow wide distribution of the system
  9. General release and distribution with firm plans for maintenance and upkeep
- 

capable of handling almost any case from its domain of expertise. A successful evaluation at Step 4 should be attained before introducing the system into the actual user environment [42:578].

Step 5 involves system evaluation in a setting where the intended users will have access to the system. A very limited number of expert systems have reached this stage of assessment [42:578]. Step 6 is intended to gain a wider



range of test case experience and to develop familiarity with real world intricacies. Step 6 is commonly referred to as "field testing" and involves extended periods of on-site performance evaluation [42:578].

Step 7 involves follow-up studies to demonstrate the system's large scale usefulness. Formal measurement of pertinent parameters are accomplished before and after introduction of the system to the large user group. The systems efficiency, cost effectiveness, and the systems acceptability to users are issues of concern during this step of developmental evaluation [42:578].

Step 8 may involve programming changes or modifications required because of problems discovered during the previous step. Once the problems are resolved, wide-scale distribution of the system is appropriate. The final step, Step 9, includes the on-going evaluation of the system to determine if the system is succeeding in the broad marketplace. The system's credibility is likely to be higher if the first eight steps were accomplished giving a solid base of data to support any claims of performance [42:579].

Figure 10 represents a Management Information System (MIS) evaluation model. Assessment of attitudes, value perceptions, information usage, and decision performance are made throughout the development and implementation process of the MIS [28:43].

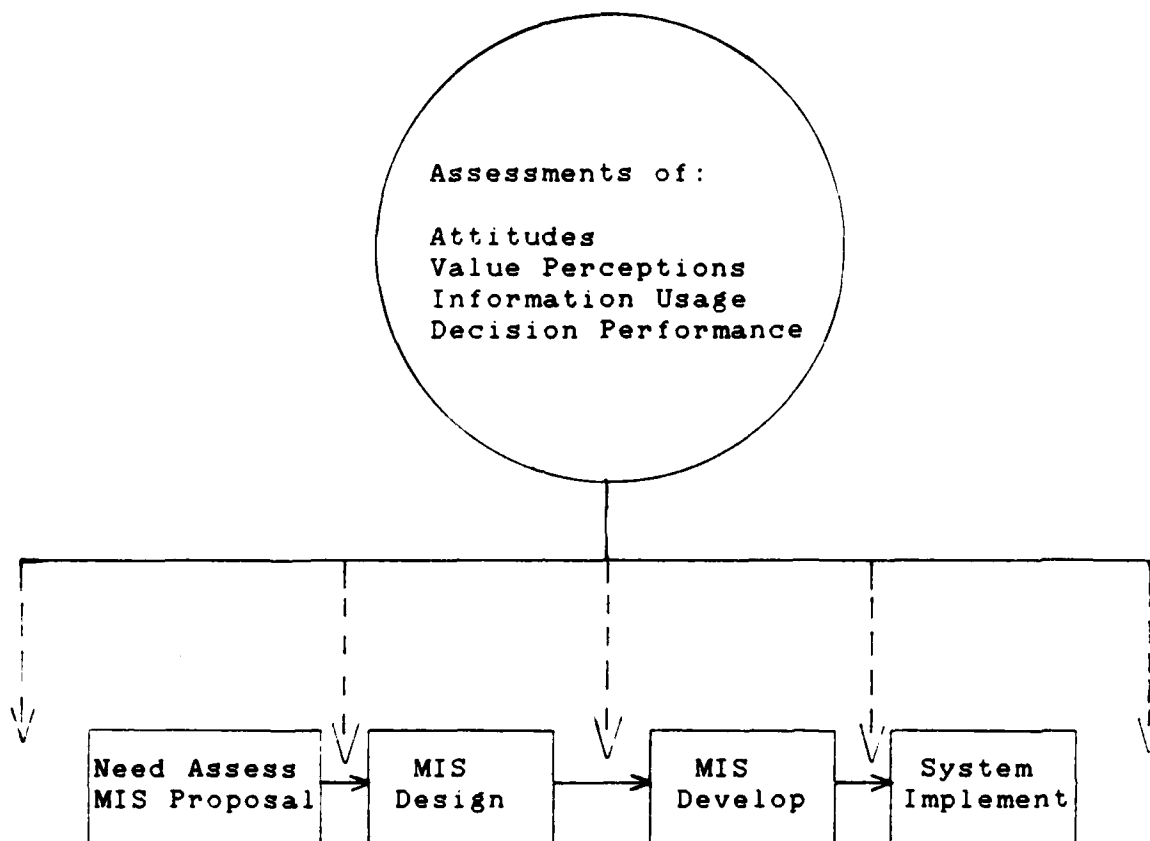


Figure 10

MIS Evaluation - Conceptual Model [28:44]

It is good programming practice to test any program in various ways throughout its development. Testing should be integrated into the development-application cycle [38:42]. Figure 11 depicts an example of a staged approach for the development and application of an expert system.

---

PHASE I

SELECTION OF  
APPROPRIATE  
PROBLEM

PHASE II

DEVELOPMENT  
OF  
PROTOTYPE  
SYSTEM

PHASE III

DEVELOPMENT  
OF  
COMPLETE  
SYSTEM

PHASE IV

EVALUATION  
OF  
SYSTEM

PHASE V

INTEGRATION  
OF  
SYSTEM

PHASE VI

MAINTENANCE

---

Figure 11

Staged Approach for development of an Expert System [20:451]

What to Evaluate. An important step in any evaluation is to determine what should be assessed. Three general areas of MIS assessment, attitudes and value perceptions, information usage, and decision performance, are discussed below.

Attitudes and Value Perceptions. Commonly informal, post-implementation assessment of a MIS is all that is made. Most systems are developed without a formal evaluation of the attitudes of the users and the organization's managers [28:45].

Decision Performance. Decision performance reflects the quality of the decision-making process both in terms of effectiveness and efficiency [28:45]. The evaluation of decision performance is very difficult because the nature of expert systems solutions are not conducive to clear cut right or wrong answers to the problems addressed by the system [3:83].

Information system evaluations are commonly provided only in efficiency oriented terms on a post hoc basis by system users [28:45]. The lack of 'pre-vs-post' system comparisons is a serious deficiency in the assessment of information systems [28:43]. The emphasis for most information system evaluation, to date, has been efficiency oriented rather than effectiveness oriented [28:43].

Information Usage. Related to decision performance is the assessment of information acquisition and usage.

A new system may affect the user's behavior. Evaluation of the user's procedures in obtaining information and determination if the user is using more relevant information can be measured [28:45].

A related evaluation subject is the measurement of the interaction capabilities of the system with the user:

1. The choice of words used in the questions and responses generated by the program
2. The ability of the expert system to explain the basis for its decisions and customize those explanations appropriately for the level of expertise of the user
3. The ability of the system to assist the user when he or she is confused and wants help
4. The ability of the system to give advice and to educate the user in a congenial fashion so that the frequently cited psychological barriers to computer use are avoided [42:575]

Performance evaluation should measure the responsiveness of the information system [13:375]. The responsiveness of an information system is based on three main factors:

Power - the degree to which the system (including its human element) can answer the most important questions.

Acessibility - the degree to which the system can provide these answers in a timely and consistent manner.

Flexibility - the degree to which the system can adapt to changing needs and situations [13:375]

How to Evaluate. Due to the nature of problems that expert systems address, evaluation of system performance is extremely difficult.

No one knows how to evaluate human expertise adequately let alone how to evaluate the expert systems that attempt to recreate that expertise [22:277]."

Further, few changes affected by an information system can be so isolated that their effects on the organization can be measured directly [13:614]. Methods to indirectly measure the effectiveness of the user as a result of interaction with the expert system exist. These methods include:

Significant task relevance - approximation of improved decision quality through users subjective estimates.

Willingness to pay - users asked to specify how much they are willing to pay for a specific report or system capability.

System usage - appropriate for systems whose usage is voluntary; system logs may permit measures of system use or users may be asked to estimate their use of the system.

User information satisfaction - users are asked to rate their satisfaction with such aspects of the system as response time, turnaround time, vendor support, accuracy, timeliness, format of outputs, and confidence in the system [13:614].

Indirect measurement of information systems are most effective when taken before and after a new system is introduced [13:614]. This allows comparative measurement of operations. System measurement is not optimal shortly after a system is implemented because of program errors, difficulties in learning new procedures, and general resistance to change [13:614].

Evaluations require an objective standard with which the results of the evaluation methodology can be compared

[42:579]. If the expert system can suggest solutions comparable to the chosen standard for the selected domain, then the expert system should be more convenient and less expensive to use than the established standard [42:580].

There are two basic ways to define the standard used for an evaluation of an expert system:

- (1) what eventually turns out to be the correct answer for a problem (in some objective sense) or
- (2) what a human expert (or group of them), presented with the same information available to the program, say is the correct answer [22:262].

The standard used to evaluate an expert system must be carefully selected as this standard will have a major impact on the quality and the results of the study [3:84]. To date, the evaluation of expert systems has primarily been done by a panel of experts which compared the expert system's recommendation to the recommendations of other human experts [2:11]. When using the decisions of the domain experts as the objective standard for performance evaluation, the domain experts themselves should be rigorously evaluated [42:580]. By evaluating the experts with a well accepted and documented technique, further credibility regarding the evaluation of the expert system is achieved [33:580].

In determining the overall validity of a system, it is instructive to determine how well human experts do in the problem area and to thereby create reasonable expectations of the system's performance. If human experts incur a 15% error rate, should the system be expected to perform better? If so how much better, and why [33:46]?

By stating the methods and intent of an evaluation experiment potential difficulties can be avoided and evaluation results are less open to misinterpretation [22:278]. Table 4 offers specific guidance to be considered during the evaluation of an expert system.

Table 4  
Evaluation Checklist [22:278-279]

---

1. Specify for whom the evaluation is intended. This greatly influences the design of the evaluation. Clearly, the informal evaluations usually performed for system builders and expert collaborators would not be sufficient for financial supporters or for society.
  2. Define precisely what is being evaluated. Isolate those aspects of the system that are being tested. Is it the quality of the system's decisions and advice, the correctness of the reasoning mechanism, the quality of the human-computer interaction, the system's efficiency, its cost-effectiveness, or some other aspect?
  3. Select an appropriate gold standard against which to compare the expert system's performance.
  4. Define realistic standards of performance: it may be unreasonable, for example, to expect better performance from the expert system than from a human expert.
  5. Specify who will be evaluating the results. It could be human experts or end users it could be individuals or a group evaluating by consensus, and so on. (Note that persons evaluating the results need not be the same as those for whom the evaluation is intended.)
  6. Eliminate potential bias, for example by avoiding presenting the results in the form of computer output, which may bias judges who feel negative toward computer technology.
  7. Specify the type of test cases presented -- random cases preselected to range over a broad spectrum of difficulty.
-



### Validation

In addition to the processes of designing, developing, and implementing expert systems, validation is important to the decision-making success of a system and to the continued use of an expert system. An expert system that has not been validated sufficiently may make poor decisions. This can lead to a loss of confidence in the particular expert system or in other systems, resulting in discontinued use and financial loss [35:468].

Validation should not be confused with verification. Verification involves testing of the accuracy of each rule and establishing a justification for each rule in the knowledge base of the expert system [51:160]. Validity is the "extent to which a measure accurately represents a variable as conceptualized [16:42]." During system validation, "the knowledge engineer presents cases solved by the expert and the prototype system to other experts. This provides a way to compare strategies of different experts and find essential points of disagreement [51:160-161]." The validation process requires:

1. ascertaining what the system knows, does not know, or knows incorrectly
2. ascertaining the level of expertise of the system
3. determining if the system is based on a theory for decision making in the particular domain
4. determining the reliability of the system [35:469]"

As previous analyses have noted, expert system validation should consist of periodic informal testing rather than

a single formal validation at the end of the project [35:469]. Ensuring that the meaning and content of knowledge base rules meet some carefully designed criteria of adequacy is the basis of validation [33:42]. 'Defining such criteria is the key to successfully conducting a validation procedure and demonstrating the level of acceptability of the knowledge base [33:42].'

O'Leary offers a framework for expert system validation procedures outlined in Table 5. The first step in the validation process involves content validity [35:472]. Content validity refers to the determination of what the system knows, does not know, or knows incorrectly and can be ascertained by direct examination of the system components or by testing the system [35:472].

Criterion validity for an expert system validation, the next step in O'Leary's validation framework, refers to the level of the system's expertise [35:475]. A comparison of the decisions made by the system and decisions made by human experts is the primary method used for expert systems [35:475]. This comparison is difficult because of differing definitions about the level of expertise, knowledge-base criteria, and a lack of clarity about what is being evaluated [35:475].

The next step in the framework offered by O'Leary is construct validity [35:473]. Construct validity tests the basic concepts upon which the expert system was developed

[35:476]. The construct validation process checks for strong relationships where they are supposed to exist as well as checking for the absence of relationships where they are not supposed to exist [16:264]. Construct validity suggests that an empirical approach to system validation is not as efficient a testing process as an approach based on the basic concepts of the problem domain [35:476].

Objectivity is another aspect of the validation process. Objectivity refers to minimizing observer variance, specifically judgemental variance in the case of expert system validation [35:476]. Reduction of judgemental variance, expert bias, can be achieved by administering the test independently and by using blinding techniques [35:476]. Blinding techniques, for example, keep the researcher from knowing which treatment group any particular test subject belongs to [16:83].

The cost-benefits of the expert system should also be considered [35:477]. System benefit is difficult to measure and is ultimately tied to how the system will be used [35:477]. Two factors that determine the cost of validating a system include the formality and the depth of the validation required [35:477]. Cost-benefit affects the scope of validation and the development of the system [35:477]. For example, an expert system that requires a limited input of time and money to develop and implement, generally will not receive as extensive a validation as an expert system that

will require a substantial commitment of resources by the using organization.

Reliability refers to the ability of the system to generate identical solutions given identical inputs [35:478]. "Reliability refers to the stability or consistency of the values that are obtained [16:42]." Expert system reliability testing can be achieved using sensitivity analysis or measurement against standard test problems [35:478].

"In validating an expert system's performance, the test problems used need to allow the validator to distinguish between systematic variance and chance [35:478]." Test problems should represent the type of problems that the human expert encounters in practice [35:478]. A range of test problems from simple to complex should be used in the validation process [35:478].

Extraneous variance should be controlled and minimized [35:479]. The influences of independent variables outside the purposes of the study should be isolated [35:479]. The complexity of the expert system, location in the system's development life cycle, amount of specialized features in the system, location of the judges during testing, and learning by the judges during testing can influence the quality of system output [35:479-480]. By reducing the number of variables that are subject to change the extraneous variance is reduced and internal validity is

Table 5

Summary of Validation Framework [35:473]

- 
1. Content validity
    - a. Direct examination of the system by the expert
    - b. System test against human experts (Turing test)
      - (1) Intraexpert test
      - (2) Interexpert test
    - c. System test against other models
  2. Criterion validity
    - a. Definition of the level of expertise of the system
      - (1) Human evaluation criteria
      - (2) Test problems to define the level of expertise
      - (3) Quality of responses defined
    - b. Knowledge-base criteria
    - c. Clarification of evaluation criteria
  3. Construct validity
  4. Objectivity
    - a. Programmer validation
    - b. Independent administration of validation
    - c. Sponsor/end-user validation
    - d. Biasing and blinding
    - e. Different development and test data
  5. Economics (cost-benefit)
  6. Reliability
    - a. System test against itself (sensitivity analysis)
    - b. Test problems for revalidation
  7. Systematic variance (experimental variance)
    - a. Problems reflecting range of problems encountered
    - b. Variation in the test problems
    - c. Number of test problems
    - d. Type I and Type II errors
  8. Extraneous variance
    - a. Complexity of the system
    - b. Expert system's location in the life cycle
    - c. Recognition, examination and testing of special fixes
    - d. Location of judges during testing
    - e. Learning on part of judges
  9. Error variance
-

increased [16:35]. By confounding variables the number of plausible explanations for the experimental results increases.

One reason why researchers prefer to do experiments--to manipulate a variable--is that manipulation gives them the opportunity to minimize or avoid confounding of relations [16:37].

Error variance is another consideration during expert system validation [35:480]. Error variance can be caused by a variation in the human expert's responses from trial to trial, guessing, momentary inattention, slight temporary fatigue, lapses of memory and transient emotional states [35:480]. This form of variance can be minimized by using proven measurement scales and by asking unambiguous questions [35:480].

Marcot considers the development of a knowledge base to proceed through four phases: creating the prototype, developing the first generation rule set, testing and expanding the rule set to the second generation, and testing the second generation rule set [33:42]. Specific validation criteria and testing procedures should be integrated within each of the four phases [33:43].

During the creation of the prototype, validation helps define the original problem and the first set of rules to frame the inference structure [33:43]. Testing of the prototype expert system should determine if the original problem domain was narrowly enough defined [33:43].

The main goals of validation during the first generation rule set phase are to reexamine the original objectives, more precisely determine the problem domain, and establish the degree of detail desired in the system [33:44]. This validation phase, alpha-testing stage, attempts to determine the accuracy and adequacy of the system [33:44]. The number of correct predictions made by the expert system are compared with known data to determine accuracy [33:44]. Adequacy may be expressed as a simple fraction, the number of problem domain conditions included in the expert system divided by the total number of important problem domain conditions [33:44]. The capacity of the knowledge base to predict, diagnose, classify, or monitor within a specified confidence interval is also measured during the alpha-testing stage [33:44].

During the expansion to a second generation rule set, the characteristics of the full-scale system should be described [33:44]. The flexibility or adaptability of the system for future applications should be determined during this phase of validation [33:44].

Testing the second generation rule set at the site where the system will be used involves technical and operational validation [33:44]. Testing should be conducted to measure user acceptance of the system and to determine how well the system integrates with existing procedural and administrative systems in the problem domain [33:44].

The main steps in conducting validation tests for each phase of knowledge base development include:

- defining the domain and context within which a system is expected to perform well and thus the contexts in which its performance is poor or unknown.
- identifying specific performance criteria for validation.
- conducting the validation tests and analyzing and evaluating the results [33:45].

Performance criteria should be specified in unequivocal terms so a test can be conducted that will prove or disprove that the knowledge engineering has accomplished the required task. Formulation of specific performance criteria also focuses attention on the precise nature of the initial conditions and the final output that the system is expected to produce [23]. Specifying the minimum acceptable performance that will allow the system to be considered a success and involving the system users early in the formulation of performance criteria is important to the success of an expert system [51:198]. Specific criteria that may be used to test the validity of a knowledge base are listed in Table 6.

#### Applications of Expert Systems

The first two sections of this chapter have reviewed the process of selecting a problem task for expert system development and the consequent performance measurement of the expert system application. This section will describe actual expert system applications and their reported



Table 6

Validation Criteria [33:46-47]

---

Accuracy: how well a simulation reflects reality. Compare inferences made by rules with historic (known) data, observe correctness of the outcome.

Adaptability: possibilities for future development and application.

Adequacy: the fraction of pertinent empirical observations that can be simulated.

Appeal: usability; how well the knowledge base matches our intuition and stimulates thought; practicability.

Availability: existence of other, simpler, validated knowledge bases that solve the same problem(s), important for determining eventual marketability.

Breadth: proportional to the number of rules used in the knowledge base. Determine the number of contexts within which the system should be expected to perform.

Depth: Determine the range of conditions the system will address and which parameters are necessary to diagnose, classify, and/or advise for each condition.

Face validity: model credibility. Have experts review system throughout development project. Compile and report results.

Generality: capability of the knowledge base to be used with a broad range of similar problems.

Precision: capability of a model to replicate particular system parameters; number of significant figures used.

Realism: accounting for relevant variables and relations. Establish parameters and functions in the rule base in the same terms and concepts used by experts or end user audience.

Reliability: the fraction of model predictions that are empirically correct. Ultimately describes statistical utility of the likelihoods in the rules and outputs.

Table 6 (Continued)

Resolution: the number of parameters of a system the model attempts to mimic. Identify which parameters need to be defined in detail and which do not.

Robustness: conclusions that are not particularly sensitive to model structure. Determine which input parameters are least and most significant in the form of the interim and final results and output.

Sensitivity: the degree to which variations of knowledge base parameters induce outputs that match historical data. Specifically determine sensitivity of results to each input parameter by varying that parameter incrementally, holding all other parameters constant and matching model output with historical (known) data.

Technical and operational validity: identification and importance of all divergence in model assumptions from perceived reality. Carefully explicate the contexts, conditions, and assumptions that underlie the rules.

Turing test: assessing the validity of a knowledge base by having human evaluators distinguish between the model's conclusions on a specific problem and a human expert's conclusions solving the same problem.

Usefulness: validates that the system contains necessary and adequate parameters and relationships for use in problem-solving. Usefulness is trivial for a full-scale system but important for prototyping.

Validity: a knowledge base's capability of producing empirically correct predictions. Given the contexts within which the system is expected to operate well, determine how many actual conditions the system can accurately diagnose.

Wholeness: the number of processes and interactions reflected in the model. Consider wholeness in light of adaptability.

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performance measurements in terms of efficiency, effectiveness, or a combination of both efficiency and effectiveness. The majority of literature reviewed described expert system performance evaluation in terms of a subjective appraisal. Literature offering purely subjective appraisals of expert systems were not included in this review.

Expert systems have been the subject of considerable research since the early 1970's but have only recently come into widespread use for business applications. Harmon and King state:

Many Fortune 500 corporations are assembling AI departments, venture capitalists are rushing to invest in entrepreneurial expert systems companies, and expert systems technology is well on its way to commercial success [23:1].

Effectiveness. MYCIN is an expert system designed to assist medical specialists in the diagnosis of infectious blood diseases and to prescribe the proper antibiotics for the diagnosis suggested [47:6]. Five faculty fellows in the Stanford Division of Infectious Diseases were asked to evaluate 15 cases for which MYCIN offered therapy advice. MYCIN received an approval rating of just under 75% of the cases tested. A second study of MYCIN performance used five evaluators from Stanford and five from medical centers located across the country. Despite the refinements made to the earlier MYCIN knowledge base, the approval rating remained approximately 75%. A further study revealed that even infectious disease faculty members rarely received a

70-80% approval rating from other experts in the field [42:582]. In their book Artificial Intelligence: a personal, commonsense journey, William R. Arnold and John S. Bowie suggest that expert systems should be 80% reliable and that humans have been about 60% reliable in their decision making historically [7:68].

An expert system developed by Ford to diagnose maintenance problems with robots, covers 20% of the rules regarding robot maintenance. This coverage is considered by the Ford experts to account for 60-80% of the problems people typically encounter. User response, after initial resistance, has been favorable and effectiveness should increase due to level of maintenance problem coverage provided by the system [12:24].

ASDEP is a prototype expert system for designing a power plant's electrical auxiliary system [26:56]. The expert system was informally evaluated by recognized human experts from Southern Company Services Incorporated [26:62]. ASDEP was rated against four factors: load groupings; bus voltage selections; equipment selections; system topology [26:62]. The ASDEP system effectiveness was rated favorably by the human experts, suggesting power plant designs similar to those suggested by the human experts. The economic efficiency of designs was not considered by the ASDEP system. Changes, to include an economic evaluator in the system, were recommended by the evaluation team [26:64].

Internist-1 is an expert system that provides internal medicine diagnoses [17:89]. The system misdiagnosed 18 out of total of 43 cases [17:89]. Clinicians at Massachusetts General Hospital misdiagnosed 15 of the same 43 cases tested with the expert system [17:89]. When panels of doctors were tested, only 8 of the 43 cases were misdiagnosed [17:89].

Helmut Braun of the University of Florida and John Chandler of the University of Illinois have developed an expert system that predicts intermediate fluctuations in the movement of the stock market for nonconservative investors [9:415]. The system's predictions of actual market movements were more accurate than the system's predictions of the expert's recommendations [9:422]. The system correctly predicted actual stock market movements for 64.4 percent of the example cases tested [9:421]. In comparison, the human expert used for the study, correctly predicted stock market movements for 60.2 percent of the 108 example cases tested [9:421].

Efficiency. A marketing expert system, More/2, is designed to identify direct mail buyers. The system targets people most likely to respond to mail order sales. The system has demonstrated that by mailing to the 50% of an existing list most likely to respond, a response rate equal to 70-80% of the response achieved when the entire list is used can be attained [12:25].

SPINPRO is an expert system that makes the centrifuges sold by Beckman Instruments easier to use and more efficient [49:5]. The system allows lab technicians to reduce centrifuge run times by as much as 70 percent of the time formerly required [49:5].

PlanPower, a financial planning expert system, allows the staff of Evensky & Brown to produce a moderately complex financial plan that once required approximately 50 hours of computer time in 10 to 15 hours [12:19].

Ken Lindsay and Bob Joy of Northrup Aircraft Division have developed an expert system to help in the design and manufacture of military aircraft. Their system has reduced the typical process planning time to a fraction of the original 8-12 hours [12:22].

CORA (Customer Order Relaying Assistant) is an expert system used by Westinghouse engineers to select diverse relay protection system configurations. The system reduces the time required to configure relay systems and ensures that the relays will work properly [12:23].

Major Stephen R. Leclair, USAF, has developed a multi-expert knowledge system that reduces the baking time for graphite reinforced lamination, used for airframe parts, from 12 hours to less than three hours [38:141].

Effectiveness/Efficiency. The Digital Equipment Corporation (DEC) uses a combination of six expert systems to automate their VAX computer sales, engineering, manufactur-

ing, and customer service operations. The XSEL expert system designs a computer system to meet the customer's specific needs. XCON, in operation since 1979, converts the design into a bill of materials and a configuration diagram. XSITE generates an equipment layout from the configuration diagram while ISA schedules the manufacturing of the order. ILOG helps resolve delays during the manufacturing process. INET routes the order from the factory to the customer [40:65]. The series of expert systems just described can now design, package, and distribute a VAX computer system better than the best DEC technician [47:17]. The system is saving DEC 20,000 dollars a month [6].

Another example of an application of expert systems is the Intelligent Scheduling and Information System (ISIS) developed by Carnegie-Mellon University. ISIS is one of several systems that are integrated within the Intelligent Management System (IMS) project. IMS is a subproject of the Factory of the Future project. ISIS is now used by Westinghouse to schedule the efficient use of its own job shop activities [27:38]. Most of the costs of producing products in complex organizations can be attributed to overhead, which includes managerial, professional, and salaried personnel costs [19:32]. ISIS is a step toward improving both professional and managerial productivity by reducing the time required to make complex management decisions and by increasing the accuracy of the decisions made [19:32].

Du Pont expects to create 2,000 expert systems by 1991 yielding a 10 percent increase in net profits this equates to approximately \$150 million. Du Pont considers payoff from a typical successful expert system to be 10-to-1 or better. A new system could save the company as much as a half million to a million dollars a year after an initial investment of only \$20,000 [52:36].

American Express's authorization assistant is an expert system designed to help company authorizers decide whether or not to approve individual credit card charges. Despite the system's fledgling status, performance to date suggests authorizer productivity will improve by 20-30%. This improvement translates into millions of dollars for American Express. The 800 rule system has impressed its human counterparts with the quality of its advice [12:17].

COCOMO1 is a microcomputer based expert system that allows developers to estimate project cost and effort requirements [53:52]. The system, developed by Barry W. Boehm, is used by many corporations including the National Aeronautic and Space Administration [53:52]. The system can reduce the time required to develop an estimate from half a day to half an hour [53:52]. Boehm estimates his system yields results within 20 percent of actual costs 68 percent of the time [53:56]. An actual corporate user of the system estimates performance of the expert system to be within 20 percent of actual costs 100 percent of the time [53:56].



Xerox has developed an expert system for the design of paper handling systems called PRIDE [34:102]. The PRIDE system has been tested on actual paper transport problems from previous and current copier projects [34:113]. PRIDE has produced satisfactory designs for many of the problem cases tested [34:113]. PRIDE can produce a design that typically takes an engineer weeks to create in 30 minutes [34:113]. PRIDE also performs a comprehensive analysis and report generation procedure [34:113]. Xerox is still in the early stages of system evaluation and plans to report more on performance in later papers [34:113].

New applications of expert systems in the DOD and defense related industries are also increasing. For example, the Central Integrated Test System (CITS) Expert Parameter System known as CEPS is a leading application of expert systems to aircraft maintenance. CEPS, when fully implemented, will provide enhanced diagnostic capabilities to B-1B maintenance technicians. The system will provide a single integrated source of maintenance history and list ongoing diagnostic activities. CITS, the embedded diagnostic system, will provide fault detection, fault isolation, and will record approximately 19,600 parameters in flight [36:211]. CEPS will reduce fault isolation time and improve the accuracy of diagnosis. Initial tests demonstrated a 30 percent reduction in 'can-not-duplicates' and 'retest-okays', and a 30 to 60 percent reduction in the test times

for line replaceable units [5:3]. CEPS is anticipated to save over \$160 million in life cycle costs [5:3].

Hughes Artificial Intelligence Diagnostic Expert System (HAIDEX) is a recent research effort aimed at assisting depot level repair activities [5:2]. By storing past maintenance history of problem symptoms and the eventual solution HAIDEX directs troubleshooting directly to the most probable fault. HAIDEX is used in an interactive mode with the technician during the troubleshooting session. Explanations of the reasoning used by the system are invaluable for training and debugging the system. Evaluation proved the HAIDEX prototype to be equal to human experts in solving difficult problems [5:3]. When tested, the system never made an erroneous diagnosis and resolved the problems in less time than human counterparts who were tasked to solve the same problems. HAIDEX appears to be superior to the novice technician. In one test the novice worked eight hours on a problem, then gave up, HAIDEX satisfactorily isolated the fault in 36 minutes [5:3].

The Air Force's first expert system is currently being fielded. IMA, the Inventory Manager Assistant, was developed by Dr. Mary K. Allen to assist item managers with the routine data review of the following elements of the D041 Requirements Computation:

- Unit Cost
- Date of Last Procurement
- Administrative Leadtime
- Production Leadtime

Base Processing Time  
Reparable Intransit Time  
Supply to Maintenance Time  
Depot Repair Cycle Time  
Turn-in Time [4:1]

The D041 Computation System computes replenishment spares requirements for reparable items. The IMA system was developed with the M.I. shell, a product of Teknowledge, and runs on any IBM compatible microcomputer with 512k of RAM. IMA acts as a consultant to item managers during their quarterly validation of requirements for reparable items [3:4]. Dr. Allen's research showed that IMA improved overall item manager performance on both simple and complex cases between 7.6 and 10.4 percent [3:185]. Performance was improved between 15.1 and 17.73 percent for complex cases [3:185]. These figures strongly suggest that expert systems can improve the decision effectiveness of inventory managers. Findings regarding the ability of IMA to improve decision efficiency were inconclusive [3:185].

#### Summary

The objective of Chapter II was to review the literature in order to gain a broader understanding of the issues involved in the development and evaluation of an expert system. The selection of a suitable problem for expert system development was discussed first, followed by performance evaluation issues and validation criteria. The final section of the chapter reviewed actual expert system applications.

The importance of selecting an appropriate problem for expert system development was discussed. Task selection criteria were reviewed that identify problems most suited for expert system application. The problem selection methodology used to identify asset reconciliation as a potential task for expert system development was then described.

The literature review detailed the importance of an evaluation procedure that is integrated throughout the development and implementation of an expert system. Evaluation should include assessments of attitudes, information usage, and decision performance. The difficulty involved in the evaluation of an expert system was described along with techniques to resolve the problems associated with performance measurement of expert systems. A framework for the validation process of an expert system and specific validation criteria were presented to identify to the reader issues related to the testing of an expert system.

Expert system applications were reviewed to show the range of uses for such systems and to describe the actual performance measurements of the systems. The majority of literature describing expert system performance was purely subjective. The lack of objective expert system performance measurement was attributed to the difficulty of measurement.

The problem selection and performance evaluation issues discussed in Chapter II were incorporated into the methodology presented in Chapter III.

### III. Methodology

#### Overview

This chapter describes how the following research questions were addressed and tested.

1. Is asset reconciliation a suitable problem for application of an expert system?
2. Can the knowledge needed to solve the selected problem be extracted from the experts?
3. Can the rules needed to perform an asset reconciliation be encoded using the Teknowledge M.1 software program?
4. How does the developed expert system prototype affect the productivity of the using organization?
  - a. Does use of the expert system increase effectiveness by at least 15%?
  - b. Does use of the expert system reduce the time required by the item manager to complete an asset reconciliation?
  - c. What is the user's subjective evaluation of the assistance provided by the expert system for asset reconciliation computations?
5. How significant is experience level in determining performance level when assisted by the expert system? Does use of the expert system help less experienced item managers more than experienced item managers?

The research conducted to answer each of these questions was composed of three main phases: Problem Selection;

Knowledge Engineering; and Performance Measurement. Each of the phases are discussed in turn in the following sections.

The overall research methodology for this thesis closely followed the 1986 research design used by Dr. Allen during her development of the Inventory Manager Assistant expert system.

#### Problem Selection

The objective of this phase of research was to select a problem to be addressed by the expert system and to choose domain experts whose knowledge would be encoded into the expert system to solve the selected problem. This initial phase of research consisted of four steps.

Step 1 - Task Selection. This step involved a review of 26 inventory management tasks considered to be most suited for expert system application in the study being validated by this research. The methodology used to develop this listing of tasks was described earlier in Chapter II. The researcher considered each of these 26 tasks in turn as a possible task for expert system development. Dr. Allen's research, listed asset reconciliation among the seven most promising tasks for expert system development. The asset reconciliation computation was also considered a narrow enough problem task for the thesis project.

Warner Robins Air Logistics Center (WR-ALC), Directorate of Materiel Management (MM), Robins Air Force Base, Georgia, was tentatively chosen as the location for the

project since the organization had demonstrated an interest in expert system development in the past.

Step 2 - Initial Domain Analysis. Step 2 entailed the researcher reviewing written documentation concerning the asset reconciliation task. The objective was to gain a basic familiarity with the process of asset reconciliation. Once a basic knowledge of asset reconciliation was attained, the suitability of the task for expert system development was evaluated using the following selection criteria:

1. There are available experts that solve the problem.
2. Task performance is significantly effected by knowledge and experience.
3. The task is clearly defined and easily scoped.
4. The task involves the manipulation of large quantities of information using heuristics, pattern matching, and search procedures.
5. Solution of the task using an expert system is expected to provide a significant payoff for the using organization.
6. Strong senior management support exists for the development of an expert system.
7. Intended users of the system would accept and use the resultant system [37:26-30].

The researcher considered asset reconciliation to meet the necessary requirements of the first five criteria. Discussions with Col Gregory, the Materiel Management director, at

Warner Robins Air Logistics Center confirmed senior management support for the development of an asset reconciliation expert system. User acceptance was considered to be an unknown factor.

Step 3 - Initial Project Meeting. The researcher met with key personnel at WR-ALC/MM to describe the proposed effort. Expected project deliverables and required resources were discussed.

Expected deliverables included:

1. A prototype expert system for asset reconciliation.
2. Test results regarding the capabilities as well as the limitations of the expert system.
3. A complete documentation of the expert system.
4. A demonstration of the system to the senior staff and to item managers for training.
5. A follow-on proposal.

Expected required resources included:

1. Human expert's time; four hours a day for a minimum of two weeks.
2. Thirty asset reconciliation cases; ten for problem identification, ten for prototype development, and ten for evaluation of the prototype expert system.
3. Problem domain information; asset reconciliation regulations, training manuals, and other



written documentation related to the completion of the asset reconciliation task.

4. On-site work space for the knowledge engineering sessions, knowledge base development, and expert system testing sessions.
5. Budget requirements were to be handled by the Air Force Logistics Command and the Air Force Institute of Technology.

A basic calendar of events, as depicted in Figure 12, was also developed during this step.

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<u>Activity</u>	<u>Date</u>
Domain Familiarization	1 Jan - 1 Mar, 1987
M.I software programming language Familiarization	1 Jan - 1 Mar, 1987
Knowledge Engineering Session 1	23 Mar - 27 Mar, 1987
Design of Initial Prototype Expert System	30 Mar - 12 Jun, 1987
Knowledge Engineering Session 2	15 Jun - 19 Jun, 1987
Evaluation of Expert System Performance	22 Jun - 26 Jun, 1987

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Figure 12  
Calendar of Major Events

Step 4 - Expert Selection. Three experts were chosen from the Materiel Management Requirements Branch. The selected experts had attended the initial project meeting. Three was considered the optimal number based on several factors:

1. Availability of personnel was constrained due to existing on-site job requirements.
2. The benefits of group interaction, multiple opinions, and a range of experiences was considered by the researcher to be important.
3. Optimum number of experts for effective management by the researcher during a knowledge engineering session.

The chosen experts were recommended by the senior staff of the organization as having extensive knowledge in the area of asset reconciliation. The sum total of applicable experience possessed by the three experts equalled 92 years. The communicative skills of the experts were also considered in the selection process. The ability to clearly and accurately express the actions needed during the asset reconciliation process was of primary importance. Completion of this step concluded the first phase of the research.

#### Knowledge Engineering

The objective of this phase of research was to extract knowledge from the selected asset reconciliation experts and create a knowledge base for a prototype expert system.

Step 1 - Case Collection. Thirty cases of actual asset reconciliation problems computed on AFLC Form 47 were collected by the three experts chosen during Step 4 of the previous phase. The researcher considered thirty cases to be a sufficient number of cases to offer a range of situations yet still be a manageable number to work with. Cases were selected by the inventory management experts to represent trivial, typical, and extreme cases of the asset reconciliation task. The researcher then systematically divided the cases into design cases, training cases, and evaluation cases, as suggested by Teknowledge Incorporated [40:11-19]. Design cases represented a small set of typical problems that the initial expert system prototype attempted to solve. The training cases were a larger set of cases used for expansion of the knowledge base. The evaluation cases were used to demonstrate the capabilities and limitations of the developed expert system [46:11-19].

Step 2 - Knowledge Engineering Sessions. The decision rules used by the experts to solve asset reconciliation tasks were obtained during this step. The Nominal Group Technique (NGT) along with the case analysis method was used to gain this information. NGT is a structured group meeting that includes the following steps:

- 1) Silent generation of ideas in writing.
- 2) Round-robin feedback from group members to record each idea in a terse phrase on a flip chart.

- 3) Discussion of each recorded idea for clarification and evaluation.
- 4) Individual voting on priority ideas with the group decision being mathematically derived through rank ordering or ratings [14:8].

The three experts met and worked as a group at all of the knowledge engineering sessions. Two distinct series of meetings were held with the experts. The first series consisted of four hour sessions each day for five days. A fourth expert was brought into the knowledge engineering process on the third day of the first series. The fourth expert was much less experienced than the other three experts. This fourth expert had only been an item manager for seven years. He was actively performing asset reconciliation as the primary function of his daily activities. The fourth expert was recommended by his supervisor as having a good understanding of the asset reconciliation process and a strong interest in the computer automation of the asset reconciliation Form 47. The fourth expert was added to the knowledge engineering process in an attempt to elicit more of the fundamental reasoning processes involved in the asset reconciliation computation. During the second series of meetings the knowledge engineer met with the four experts four hours a day for five days. All the group sessions were tape recorded.

Day One of the first series of meetings was spent developing a basic understanding of the problem task. A

brief review of the initial project meeting was accomplished first. Exercise One was then completed using the NGT. During Exercise One the experts were asked to answer five statements regarding the asset reconciliation process:

1. Define Asset Reconciliation in general terms.
2. What do you consider the most difficult part of the Asset Reconciliation process?
3. What is the most common mistake made during the Asset Reconciliation process?
4. Do certain assets require significantly different procedures during the Asset Reconciliation process? If so, what types of assets and how are the procedures different?
5. What is the objective of completing AFLC Form 47?

A copy of the written directions given to the experts during Exercise One is included in Appendix B. A consensus regarding the actual scope of the task was achieved using Exercise One and the NGT. Following Exercise One, the experts were asked to select two "typical" cases from the ten asset reconciliation cases the researcher provided for them. The cases distributed to the experts were from the original thirty cases collected during Step 1. The three experts each individually selected two typical cases, for a total of six cases selected by the experts. Then, as a group, the experts chose three cases from the six typical cases. These three cases were used during Exercise Two. Each expert used

one of the typical cases selected to conduct an asset reconciliation computation. The experts were asked to write out in specific detail how they would complete the computation and where they would find the information required for the computation. A copy of the written directions given to the experts for Exercise Two is located in Appendix C.

Day two of the first knowledge engineering session began with a review of the expert's responses to Exercise One and Exercise Two. Each of the expert's written descriptions, from Exercise Two detailing how to complete an asset reconciliation computation, were examined and commented on by the group.

Exercise Three was conducted on the third day of the knowledge engineering session. Exercise Three was used to elicit a more detailed analysis of the questions that need to be asked during an asset reconciliation computation. The approach was modeled after an experiment conducted by Coopers & Lybrand during their development of the ExpertAX expert system [30:23]. Their experiment was video recorded and used three domain experts, a novice, and a curtain. The objective of the experiment was to mimic a computer by having the three experts act as the expert system, the curtain act as the computer screen and the novice act as the user [30:23].

The experts participating in Exercise Three were asked to imagine a computer screen separating them from each

other. Expert One was seated at a table with all the supporting documentation to perform an asset reconciliation. Expert two was seated across the table from Expert One and directed to lead Expert One through the asset reconciliation process. Expert Two was not allowed to use hand motions and was asked to offer directions to Expert One in the form of questions and advice. Expert Two was asked to respond to Expert One's answers in the same way as an expert system computer program might respond, by offering solutions and prompting further actions. A copy of the written directions provided to the experts for Exercise Three is located in Appendix D.

The remaining time during the first series of meetings was spent discussing the elements of AFLC Form 47 computations and the sequence of events that occur during a typical asset reconciliation computation. Subcategories of the problem task were identified and prioritized according to importance and the frequency of being incorrectly computed. Cases were reviewed in detail by the experts and the knowledge engineer. The experts were asked to silently generate their solutions and decision protocol for the elements of the computation that the expert system was addressing. Their solutions were then examined by the group and a consensus achieved through open discussion.

On the final day of the first knowledge engineering session, a simple introductory expert system for asset

reconciliation was developed consisting of six rules using the M.I software package. The introductory system was demonstrated to the experts to provide a better understanding of how an expert system would function and to stimulate ideas regarding the further development of the asset reconciliation expert system.

Step 3 - Building the Initial Prototype System. Tape recordings of the first knowledge engineering sessions were carefully reviewed. The original knowledge base was encoded based on the facts and rules obtained from the experts during the first series of meetings. One-hundred specific rules regarding the asset reconciliation computation were included in the original knowledge base. The M.I shell was used to develop the first knowledge base system. M.I was selected in order to replicate, as closely as possible, the study being validated. Completion of this step resulted in the development of the initial expert system prototype called the Manager's Asset Reconciliation System (MARS).

Step 4 - Expanding and Verifying the System. During the second series of meetings with the experts, the MARS prototype underwent an initial verification. The knowledge engineer, i.e. this researcher, again met with the three original experts for five days, four hour sessions each day. After each of the daily four hour sessions, the fourth expert was consulted on an individual basis regarding the issues discussed during the sessions with the three experts.



The individual consultations with the fourth expert provided a greater variety of explanations regarding asset reconciliation activities. A Zenith 248 micro-computer was used throughout the verification process to add and update rules in the knowledge base of the expert system.

The experts were provided with a listing of the knowledge base coded in the M.I language at the beginning of the first session. The researcher then explained the syntax and the logic that M.I used to reach conclusions. The experts were then asked to review the knowledge base listing three separate times. During the first review, the experts checked for any incorrect rules. The second review entailed a check for faulty wording of the questions or advice listed in the M.I coding. The experts were asked to provide additions or recommended changes in terminology which would make the questions and advice clearer to a user of the system. During the third review the experts were asked to check the order in which questions were asked and advice given. The experts were asked to recommend changes that would make an interactive consultation with the system a more logical progression.

Following the verification of the knowledge base listing, the experts were introduced to the MARS prototype. The experts each ran several interactive consultations with MARS. The researcher used the remainder of the first day to make changes to MARS recommended by the experts. This

correction procedure was accomplished each day such that the system was ready for further verification the following day.

The second day began with another review of the M.1 syntax with the experts. The rest of that day and the remainder of the week were spent working through ten design cases and five training cases with the experts using MARS. The experts each took turns working at the computer terminal, keying the inputs, and reading advice offered by MARS to the other experts. The other two experts worked manually through the cases and would agree or disagree with MARS' advice based upon their manual computations. When a disagreement arose MARS was requested to show which rule had been invoked to provide the advice. The rule was then checked for accuracy.

After verification with the three experts was concluded on the morning of the fifth day, an experienced item manager and a novice item manager were introduced to MARS and asked to critique the system. These item managers were selected because they were less experienced than previous users of MARS. Neither the experienced item manager nor the novice item manager had participated in any earlier activities regarding the development of MARS. They offered an independent evaluation of the system. One of the experts spent three hours working through two training cases. The other experts were also present to explain MARS' reasoning if the experienced or the novice item manager disagreed with

MARS' output. Several changes resulting in the simplification of the system's terminology were recommended as a result of this session.

Upon completion of the verification sessions both the original three experts and the fourth expert agreed that the demonstrated performance of MARS warranted formal testing.

#### Performance Measurement

The purpose of this phase of research was to determine if the prototype expert system enhanced the productivity of inventory managers using the system. A sample consultation with MARS and the resultant output are included in Appendices I and J respectively. The following research questions were answered:

- How does the developed expert system prototype affect the productivity of the using organization?
  - Does use of the expert system increase effectiveness by at least 15%?
  - Does use of the expert system reduce the time required by the item manager to complete an asset reconciliation?
  - What is the user's subjective evaluation of the assistance provided by the expert system for asset reconciliation computations?
- How significant is experience level in determining performance level when assisted by the expert system? Does use of the expert system help less experienced item managers more than experienced item managers?

Step 1 - Experimental Model Development. A single experiment was used to measure decision effectiveness with a

two-by-two-by-three between subjects factorial design. Each subject participated in only one of the cells in the design. Figure 4 depicts the cell design for this experiment. The levels and treatments of the experiment are:

<u>Treatment</u>	<u>Levels</u>
1. Task Method	1. With Expert System 2. Manually
2. Task Difficulty	1. Simple 2. Complex
3. User Experience	1. Novice 2. Journeyman 3. Advanced

The experimental model for the effectiveness/efficiency testing can be depicted as follows:

$$X_{ijkl} = \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \alpha\gamma_{ik} + \beta\gamma_{jk} + \alpha\beta\gamma_{ijk} + \epsilon_{ijkl}$$

Where i = 2 levels of task method  
j = 2 levels of task difficulty  
k = 3 levels of user experience  
l = cell replicate

The following definitions were used for development of the experimental model:

Novice - up to one year of experience as an item manager

Journeyman - one to four years experience as an item manager

Advanced - more than four years of experience as an item manager (senior inventory managers considered four years to be the learning curve level-off point for most item managers) [3:332-333]

Efficiency - the time to complete the selected task.

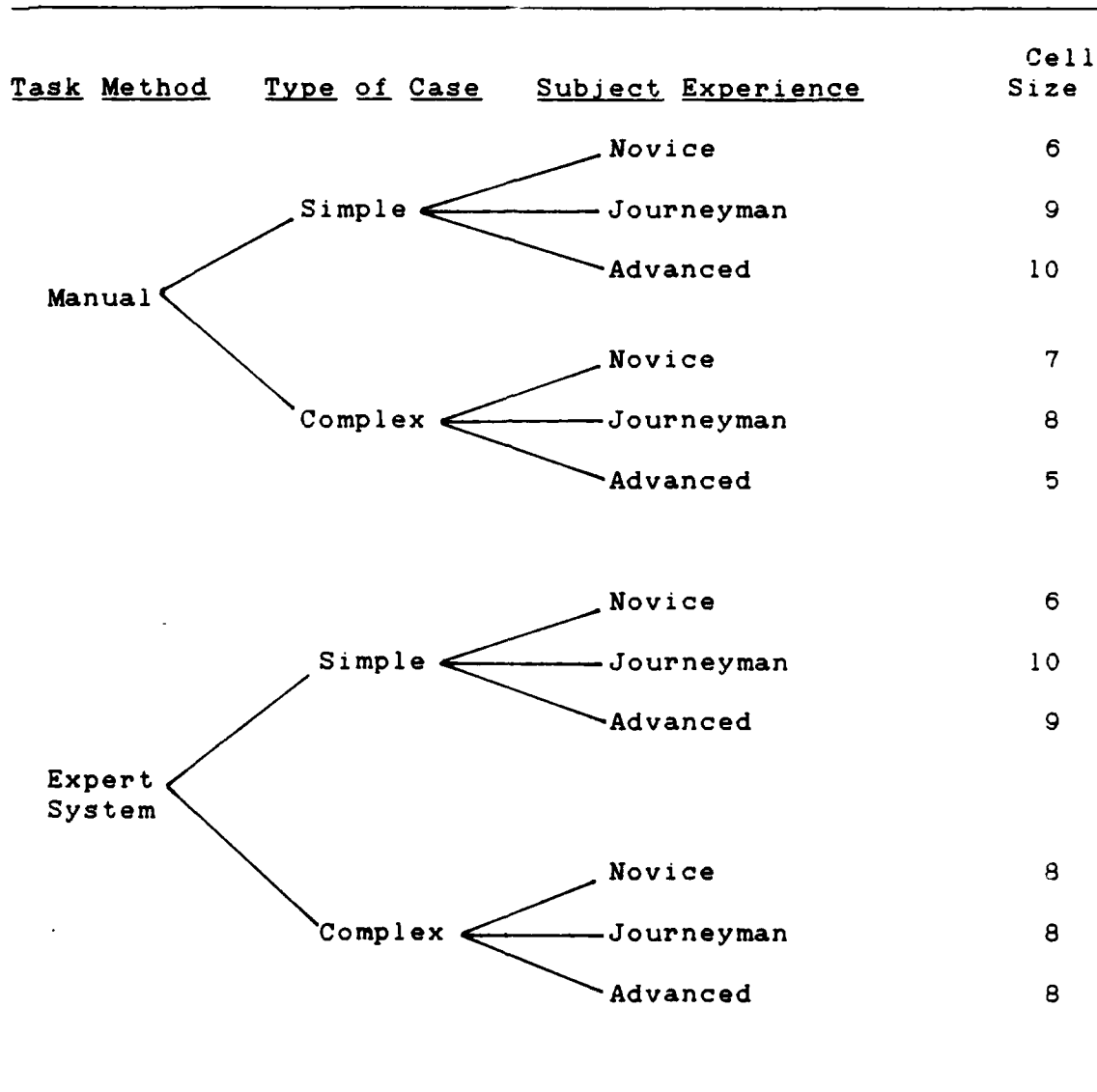


Figure 13

Cells and Cell Sizes of the  
Effectiveness/Efficiency Experiment

Effectiveness - performance score between 0 and 100 points related to the accuracy of test subject's answers as compared to a test key developed for the test cases [3:329]

Task performance, for both simple and complex test cases, was scored using the "on-hand assets", block 15, quantity from the Form 47. Four other parameters listed on the Form 47 were also informally checked to verify procedural accuracy.

1. Total acquired assets
2. Starting position
3. Balance accountable assets
4. Net balance accountable

The test subjects determined, either manually or with the assistance of MARS, a quantitative value for the "on-hand assets" and the four parameters listed above during an asset reconciliation computation. The test subject's answers were compared to the correct answers for the same problem as determined by the MARS developmental experts and their immediate supervisor. Deviation of the test subject's answers from the correct answers was measured according to the following predetermined descriptive categories: very good answer, good answer, mediocre answer, poor answer, very poor answer. Answers falling in each of the categories were assigned the following respective point values: 100, 75, 50, 25, and 0. The subject could score between 0 and 100 points on the effectiveness portion of task performance testing. Efficiency was measured as the time to complete the asset reconciliation test case. The test subjects were not aware that they were being timed.

Step 2 - Test Case Selection. This step involved the selection of a simple and complex case to be used for testing of the expert system. "A complex case was defined as a very difficult case which would be very infrequently encountered. A simple case was defined as a very easy case which would be very frequently encountered [3:130]." A sample of a complex case is included in Appendix H.

Three of the four developmental experts were directed to select a simple case and a complex case from their asset reconciliation files. Each of the three experts were then asked to grade their own cases and the cases selected by the other two experts according to difficulty and frequency encountered. No attempt was made to drive the experts opinion on these measures to consensus. Table 7 depicts the grading scale used.

The experts used the numerical scale listed in Table 7 to grade the complexity of the six cases they selected. The case with the highest combined difficulty and frequency score was selected as the complex test case and the case with the lowest combined difficulty and frequency score was selected as the simple test case. Additionally, the case with the second lowest combined difficulty and frequency score was selected as an example case to be used during the pre-test demonstration. The experts then ran the two selected cases with MARS to insure the cases were within the limits of MARS' capabilities.

Table 7  
Case Complexity Grading Scale [3:131]

Difficulty	
<u>Descriptor</u>	<u>Grade</u>
Very difficult	5
Difficult	4
Moderately difficult	3
Easy	2
Very easy	1

Frequency	
<u>Descriptor</u>	<u>Grade</u>
Very Infrequently Encountered	5
Infrequently Encountered	4
Moderately Encountered	3
Frequently Encountered	2
Very Frequently Encountered	1

Step 3 - Test Key Development. The development of a test key was completed before actual testing occurred in order to make the effectiveness performance evaluation as objective as possible. The four developmental experts were



asked to manually, without the assistance of MARS, complete the simple test case and the complex test cases selected previously.

The formally scored parameter was the quantity listed in block 15 of the Form 47, on-hand assets. Four other parameters were informally checked to determine procedural accuracy. Consensus regarding the correct responses for the test case parameters was achieved through discussion. Table 8 depicts the test key used to match the scored parameter, on-hand assets, with the quality of answer categories: very poor; poor; mediocre; good; very good.

Testing facility requirements and a planned testing schedule were also developed during this step. The request for testing facilities and participant scheduling is included in Appendix E.

Step 4 - Test Administration. The test was conducted at Warner Robins Air Logistics Center. A single, between-subjects experiment was conducted using a two-by-two-by-three factorial design. Prior to the actual testing, test subjects were asked to complete a questionnaire. The questionnaire requested the test subjects to report their level of computer experience and their level of confidence in using a computer. This information was considered during the analysis of the efficiency results. A copy of the questionnaire completed by the test subjects is included in Appendix G. Written test directions were also provided

prior to testing. A copy of the test directions is included in Appendix F.

The test subjects' performance was measured against either the simple or the complex case. The subjects were given a five to ten minute introduction to expert systems using the example case selected during Step 2. Forty subjects from the novice group, individuals with less than one year of experience as an inventory manager, were scheduled for testing by the senior Materiel Management staff. Forty subjects from the journeyman group, individuals with one to four years experience, were scheduled for testing by the senior staff. Forty subjects from the advanced group, individuals with more than four years experience as an inventory manager, were scheduled for testing by the senior staff. A total of 94 subjects out of the 120 scheduled for testing attended the testing sessions at Warner Robins ALC.

Each subject received a score between 0 and 100 points for the test case completed. The score was determined by comparing the test subject's answers to the test key scoring parameters, Table 8, and applying point values as described in Table 9. Analysis of the 94 test subjects scores was used to determine if inventory manager performance was improved through the use of the MARS expert system.

The time each subject took to complete the test case was recorded. Time was measured from the moment the subject

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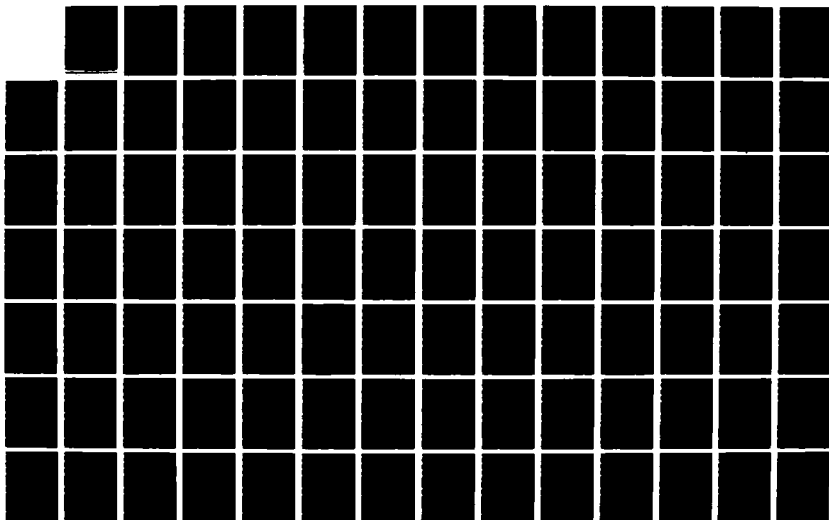
AN EXPERT SYSTEM FOR ASSET RECONCILIATION(U) AIR FORCE  
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AND LOGISTICS S A MCCAIN SEP 87 AFIT/GLM/LSV/875-46

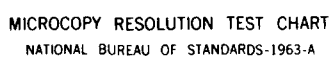
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MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

Table 8  
Test Key Scoring Parameters

Actual Error Quantity of Computed On-hand Assets, Simple Case	Quality of Answer
8 or greater	Very Poor
6 to 7	Poor
4 to 5	Mediocre
2 to 3	Good
0 to 1	Very Good

Actual Error Quantity of Computed On-hand Assets, Complex Case	Quality of Answer
21 or greater	Very Poor
16 to 20	Poor
11 to 15	Mediocre
6 to 10	Good
0 to 5	Very Good

actually began the test case until the subject finished the test case. The test subjects were unaware that the test was being timed.

The statistical significance of the effects of task method, user experience, and type of case on the two

dependent variables, effectiveness test scores and time to completion, were assessed using a univariate General Linear Model (GLM) procedure in conjunction with the SAS computer

Table 9  
Assigned Point Values for Test Subject Answers

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<u>Quality of Answer</u>	<u>Point Value</u>
Very Poor	0 points
Poor	25 points
Mediocre	50 points
Good	75 points
Very Good	10.0 points

---

analysis software program. GLM procedures use the method of least squares to fit general linear models to the data and perform an analysis of variance. GLM procedures are especially suited to unbalanced data where the cell sizes of the factorial experiment are not equal. Type III test effects, referred to as partial sum of squares, were analyzed as suggested by the SAS manual [39:466]. Hardware, software, and user system familiarity, were considered factors that affected the time to completion of the test subjects using the expert system to complete the cases.

Additionally, those test subjects who used MARS were asked to complete a qualitative critique of the expert system. The critiques were summarized but no formal analysis of the critiques was attempted. A copy of the critique form used and some representative examples of the critiques received are included in Appendices K and L respectively.

### Summary

This chapter described the methodological approach, adapted from a 1986 study by Allen, used to conduct this research project. The research design incorporated lessons learned from previous expert system development projects. Early and continued involvement of the intended users of the expert system, multiple experts, case analysis, and an objective approach to the evaluation of the expert system's performance, were key lessons that were used.

An expert system to assist inventory managers with the asset reconciliation task was developed. An experiment was conducted to determine if use of the expert system could enable managers to make more effective and efficient decisions. The results of the performance testing is the subject of the next chapter.

#### IV. Results and Other Findings

##### Overview

This chapter presents the results of the General Linear Model analysis for the effectiveness/efficiency experiment. As discussed earlier in the research methodology chapter, data was collected during the effectiveness/efficiency testing sessions. The data were then submitted to a statistical analysis using a fixed effect, two-by-two-by-three factorial model in conjunction with a computer analysis software package called SAS. The study being validated treated the subject's experience and confidence in interacting with a computer as continuous variables and used the data as covariates in the analysis. The previous study found the covariates did not explain any significant amount of variance and were eliminated from the final analysis. In order to more closely follow the study being validated, the subject's experience and confidence interacting with a computer were not considered in the SAS analysis.

A univariate General Linear Model (GLM) procedure was used to conduct an analysis of variance for both the effectiveness data and the efficiency data. An alpha level of .05 was used to judge significance. An alpha level of .10 was used to judge 'marginal' significance. The objective of the analysis was to determine the magnitude and direction of any change in total performance caused by the



use of the expert system. Interaction effects were analyzed to determine if relationships between the effectiveness/efficiency model variables existed.

The chapter first reviews the effectiveness performance scores followed by a review of the efficiency performance scores. The final section of the chapter presents other findings from the research for which no formal research questions had been established in advance.

#### Effectiveness Scores

The GLM procedures analysis did not reflect any significant three-way interaction of experience by difficulty by method. A marginally significant two-way interaction of difficulty by method was noted. The expert system improved performance on the complex case more than on the simple case. The GLM analysis reflected significant main effects of both difficulty and method main effects. The SAS analyses of effectiveness scores are shown in Tables 10 and 11.

Difficulty by Method Interaction Table 12 presents the aggregate effectiveness means for the difficulty by method interaction. The table reveals a 5 percent improvement in the scores of item managers using the expert system for the simple case and a 37.92 percent improvement for those item managers using the expert system to complete the complex case. The overall effectiveness of item managers assisted by MARS was increased by 19.45 percent.

Table 10

## ANALYSIS OF ASSET RECONCILIATION TEST CASE EFFECTIVENESS

## GENERAL LINEAR MODELS PROCEDURE

## CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
EXPERIENCE=EXPER	3	ADVANCED JOURNEYMAN NOVICE
DIFFICULTY=DIFFICUL	2	COMPLEX SIMPLE
METHOD	2	EXPERT-SYSTEM MANUAL

NUMBER OF OBSERVATIONS IN DATA SET = 94

DEPENDENT VARIABLE: EFFECTIVENESS SCORE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	11	32465.66827085	2951.42438826	1.63
ERROR	82	148764.38492063	1814.19981611	

CORRECTED			PR > F
TOTAL	93	181230.05319149	0.1064

R-SQUARE	C.V.	ROOT MSE	EFFECTIVENESS MEAN
0.179141	64.8386	42.59342456	65.69148936

SOURCE	DF	TYPE III SS	F VALUE	PR > F
EXPER	2	4690.69135587	1.29	0.2800
DIFFICUL	1	9312.34360469	5.13	0.0261
METHOD	1	9269.98732090	5.11	0.0264
EXPER*DIFFICUL	2	440.34083885	0.12	0.8859
EXPER*METHOD	2	2604.64859431	0.72	0.4908
DIFFICUL*METHOD	1	6263.65663569	3.45	0.0667
EXPER*DIFFIC*METHOD	2	9.70176745	0.00	0.9973

Table 11  
TEST CASE EFFECTIVENESS MEANS

		DIFFICUL	METHOD	N	EFFECTIVENESS	
		COMPLEX	EXPERT	24	72.9166667	
		COMPLEX	MANUAL	20	35.0000000	
		SIMPLE	EXPERT	25	77.0000000	
		SIMPLE	MANUAL	25	72.0000000	

EXPER	DIFFICUL	METHOD	N	EFFECTIVENESS	CHANGE *
ADVANCED	COMPLEX	EXPERT	8	81.2500000 >	41.25
ADVANCED	COMPLEX	MANUAL	5	40.0000000	
ADVANCED	SIMPLE	EXPERT	9	88.8888889 >	8.88
ADVANCED	SIMPLE	MANUAL	10	80.0000000	
JOURNEYM	COMPLEX	EXPERT	8	71.8750000 >	46.87
JOURNEYM	COMPLEX	MANUAL	8	25.0000000	
JOURNEYM	SIMPLE	EXPERT	10	70.0000000 >	14.45
JOURNEYM	SIMPLE	MANUAL	9	55.5555556	
NOVICE	COMPLEX	EXPERT	8	65.6250000 >	22.76
NOVICE	COMPLEX	MANUAL	7	42.8571429	
NOVICE	SIMPLE	EXPERT	6	70.8333333 >	-12.50
NOVICE	SIMPLE	MANUAL	6	83.3333333	

EXPER	METHOD	N	EFFECTIVENESS
ADVANCED	EXPERT	17	85.2941176
ADVANCED	MANUAL	15	66.6666667
JOURNEYM	EXPERT	18	70.8333333
JOURNEYM	MANUAL	17	41.1764706
NOVICE	EXPERT	14	67.8571429
NOVICE	MANUAL	13	61.5384615

\* CHANGE represents the increase (+) or decrease (-) in the effectiveness of item managers from the same experience group when assisted by MARS on the same type of case.

Table 12

Mean Total Effectiveness Scores, Difficulty by Method

Case Difficulty	Solution Method		
	Manual	Expert System	Both Methods
Simple	72.00 (25)	77.00 (25)	74.50 (50)
Complex	35.00 (20)	79.92 (24)	55.68 (44)
Both Cases	55.55 (45)	75.00 (49)	65.69 (94)

Efficiency Scores

GLM procedures were run using the time to completion data accumulated during testing. No significant three-way interaction of experience by difficulty by method was reflected in the GLM analysis. A significant two-way interaction was noted for experience by method. A marginally significant two-way interaction of difficulty by method was also noted. The results demonstrated significant main effects of both difficulty and method. Results of the SAS analyses are listed in Tables 13 and 14.

Difficulty by Method Interaction. The GLM procedures revealed a significant two-way interaction between the case difficulty and task method treatments. Table 15 depicts the aggregate means for this efficiency test interaction. The overall time to completion for item managers assisted by the expert system increased by 10.67 minutes. On complex cases, the time to completion for item managers assisted by MARS increased 6.31 minutes. On simple cases, the time to completion for item managers assisted by MARS increased by 12.48 minutes.

Experience by Method Interaction. GLM procedures also revealed significance in this two-way interaction. Table 16 describes the aggregate means for this interaction. Time to completion decreased as experience level increased for all test cases completed either manually or with MARS. The average time to completion for novice item managers assisted by MARS increased 15.96 minutes. The average time to completion for journeyman item managers assisted by MARS was increased by 12.19 minutes. The average time to completion for advanced item managers assisted by MARS was increased by 4.79 minutes overall. The largest increase in the average time to completion, 20.83 minutes, occurred when novice item managers were assisted by MARS on the simple case. The advanced item manager time to completion was reduced by an average of 4.75 minutes when assisted by MARS on the complex case.

Table 13

## ANALYSIS OF ASSET RECONCILIATION TEST CASE EFFICIENCY

## GENERAL LINEAR MODELS PROCEDURE

## CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
EXPERIENCE=EXPER	3	ADVANCED JOURNEYMAN NOVICE
DIFFICULTY=DIFFICUL	2	COMPLEX SIMPLE
METHOD	2	EXPERT-SYSTEM MANUAL

NUMBER OF OBSERVATIONS IN DATA SET = 94

DEPENDENT VARIABLE: TIME TO COMPLETION

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	11	17599.89956096	1599.99086918	14.20
ERROR	82	9239.21746032	112.67338366	

CORRECTED				PR > F
TOTAL	93	26839.11702128		0.0001

R-SQUARE	C.V.	ROOT MSE	TIME MEAN
0.655756	26.1681	10.61477196	40.56382979

SOURCE	DF	TYPE III SS	F VALUE	PR > F
EXPER	2	436.44628583	1.94	0.1507
DIFFICUL	1	12570.07187820	111.56	0.0001
METHOD	1	2017.44360942	17.91	0.0001
EXPER*DIFFICUL	2	229.81284527	1.02	0.3652
EXPER*METHOD	2	1012.41571632	4.49	0.0141
DIFFICUL*METHO	1	326.87757168	2.90	0.0923
EXPER*DIFFIC*METHOD	2	59.89964591	0.27	0.7672

Table 14

GENERAL LINEAR MODELS PROCEDURE  
EFFICIENCY MEANS

EXPER	DIFFICUL	METHOD	N	TIME	CHANGE *
ADVANCED	COMPLEX	EXPERT	8	50.2500000 >	-4.75
ADVANCED	COMPLEX	MANUAL	5	55.0000000	
ADVANCED	SIMPLE	EXPERT	9	27.2222222 >	4.82
ADVANCED	SIMPLE	MANUAL	10	22.4000000	
JOURNEYM	COMPLEX	EXPERT	8	57.2500000 >	11.00
JOURNEYM	COMPLEX	MANUAL	8	46.2500000	
JOURNEYM	SIMPLE	EXPERT	10	38.5000000 >	14.17
JOURNEYM	SIMPLE	MANUAL	9	24.3333333	
NOVICE	COMPLEX	EXPERT	8	61.0000000 >	10.71
NOVICE	COMPLEX	MANUAL	7	50.2857143	
NOVICE	SIMPLE	EXPERT	6	43.3333333 >	20.83
NOVICE	SIMPLE	MANUAL	6	22.5000000	

DIFFICUL	METHOD	N	TIME
COMPLEX	EXPERT	24	56.1666667
COMPLEX	MANUAL	20	49.8500000
SIMPLE	EXPERT	25	35.6000000
SIMPLE	MANUAL	25	23.1200000

EXPER	DIFFICUL	N	TIME
ADVANCED	COMPLEX	13	52.0769231
ADVANCED	SIMPLE	19	24.6842105
JOURNEYM	COMPLEX	16	51.7500000
JOURNEYM	SIMPLE	19	31.7894737
NOVICE	COMPLEX	15	56.0000000
NOVICE	SIMPLE	12	32.9166667

EXPER	METHOD	N	TIME
ADVANCED	EXPERT	17	38.0588235
ADVANCED	MANUAL	15	33.2666667
JOURNEYM	EXPERT	18	46.8333333
JOURNEYM	MANUAL	17	34.6470588
NOVICE	EXPERT	14	53.4285714
NOVICE	MANUAL	13	37.4615385

\* CHANGE represents the increase (+) or decrease (-) in the efficiency of item managers from the same experience group when assisted by MARS on the same type of case.

Table 15

Mean Total Efficiency Scores, Difficulty by Method

Case Difficulty	Solution Method		
	Manual	Expert System	Both Methods
Simple	23.12 (25)	35.60 (25)	29.36 (50)
Complex	49.85 (20)	56.16 (24)	53.29 (44)
Both Cases	35.00 (45)	45.67 (49)	40.56 (94)

Table 16

Mean Total Efficiency Scores, Experience by Method

Solution Method	Experience Level			
	Novice	Journeyman	Advanced	All Levels
Manual	37.46 (13)	34.64 (17)	33.26 (15)	35.00 (45)
Expert System	53.42 (14)	46.83 (18)	38.05 (17)	45.67 (49)
Both Solutions	45.73 (27)	40.91 (35)	35.80 (32)	40.56 (94)



### Other Findings

Three findings, for which no formal research questions had been established in advance, were discovered during the conduct of this research.

The first finding concerned asset reconciliation policy. Several policy operating procedures were found to be in need of review. The developmental experts questioned the value of the current worldwide inventory procedures as written in AFM 67-1. Revisions to the Form 47 were also recommended. The developmental experts suggested removing the "On-loan (Bailments)" line from the Form 47 and changing the "Transfers to R & M" line to "Transfers to DPDO".

The second finding refers to the use of Exercise Three during the knowledge engineering effort. The methodology used during the exercise proved to be especially helpful in stimulating a detailed discussion regarding asset reconciliation procedures. The exercise focused the thinking of the developmental experts and gave them a better understanding of where the knowledge engineering sessions were leading.

The third finding was determined through the analysis of the subject questionnaires which were distributed prior to the effectiveness/efficiency testing sessions. The computer literacy of the test subjects was self reported. Sixty-seven percent of the subjects tested, reported either no computer experience or limited computer experience. Sixty-one percent of the subjects tested described them-

selves as having either no confidence or limited confidence in their use of computers.

#### Summary

Chapter IV presented the results and other findings of this research project. The effectiveness of item managers who were assisted by the expert system was higher than the effectiveness of item managers who performed the test manually. A 19.45 percent improvement in the overall effectiveness of test subjects assisted by MARS was demonstrated. On complex cases, test subject effectiveness increased by 37.92 percent.

The time to completion of item managers who were assisted by the expert system was longer than the time to completion of item managers who performed the test manually. An increase of 10.67 minutes for the overall time to completion for test subjects assisted by MARS was observed. On complex cases, the time to completion for test subjects assisted by MARS was increased by 6.31 minutes.

Chapter V will present the conclusions drawn from these results and other findings.

## V. Summary, Conclusions, and Recommendations

### Overview

The purpose of this chapter is to provide an overview of the entire research project with emphasis accorded to the research conclusions and the recommendations for further study. The first section summarizes the primary objective of the research effort, the research methodology, and the research findings. The second section discusses conclusions drawn from the research and assesses the contributions made by the study. The final section provides recommendations for future research.

### Summary of Research Effort

This section will briefly review the research objective, the methodology applied to achieve the research objective, and the research findings.

Research Objective. The objective of this research was to validate a previous research finding that documented a 15 percent increase in the effectiveness of AFLC inventory managers when assisted by an expert system. The research was conducted to extend prior expert system research by developing an expert system for a different task. The development of an expert system for asset reconciliation that increased the effectiveness of item managers using the expert system by 19.45 percent validated the previous finding and extended the research of the previous study.

Ultimately, the research was undertaken to determine if an expert system for asset reconciliation could improve inventory management procedures and potentially create savings for the Government while alleviating manpower shortages.

Research Methodology. The methodological approach to the research effort involved a twelve-step process that was divided into three general phases: Problem Selection; Knowledge Engineering; and Performance Measurement. The objective of the problem selection phase was to choose a problem to be addressed by the expert system and to select domain experts whose knowledge would be encoded into the expert system to solve the chosen problem. The purpose of the knowledge engineering phase of the research was to extract knowledge from the selected asset reconciliation experts in order to create a knowledge base for the prototype expert system. The final phase of the research, performance evaluation, was conducted to determine if the developed prototype expert system enhanced the productivity of inventory managers using the system.

Research Findings. The findings of the research were grouped according to effectiveness and efficiency. The overall effectiveness of item managers assisted by the expert system was increased by 19.45 percent. The overall efficiency, i.e. time to completion of the test cases, of item managers assisted by the expert system was increased by

10.67 minutes. Three other findings, for which no formal research questions had been established in advance, were also discovered. These findings included suggested changes to asset reconciliation policy, the successful use of an expert simulation procedure during knowledge engineering sessions, and that 67 percent of the item managers tested reported either no computer experience or limited computer experience.

### Conclusions

The conclusions discussed in this section are related to the five research questions addressed by this study.

Research Question 1: Is asset reconciliation a suitable problem for application of an expert system?

Conclusion 1: Asset reconciliation was determined to be a suitable problem for application of an expert system. Asset reconciliation met the problem selection criteria described in Chapter II. The characteristics of the asset reconciliation problem demonstrated that expert system application was possible, justified, and appropriate. The effectiveness of item managers performing a complex asset reconciliation test case with the assistance of MARS was increased by 37.92 percent over the effectiveness of those item managers completing the complex test case without MARS. The increased effectiveness of the item managers supports the assumption that the asset reconciliation task is indeed suited for application of an expert system.

The positive critiques received from the subjects who were assisted by MARS during testing suggests the potential for widespread user acceptance is high. The strong user acceptance also suggests that an expert system for the asset reconciliation problem task was a suitable application.

Research Question 2: Can the knowledge needed to solve the selected problem be extracted from the experts?

Conclusion 2: The finding that test subjects assisted by the expert system had higher effectiveness scores for both the simple and complex cases suggests that the knowledge required to solve an asset reconciliation problem was extracted from the human experts. Item managers using the expert system remarked that the expert system broadened their understanding of the asset reconciliation process. One technique proved especially productive in extracting the required knowledge from the developmental experts. The Nominal Group Technique was used successfully throughout the knowledge engineering process. The Nominal Group Technique served to structure the knowledge engineering sessions and to surface underlying sources of disagreement between the developmental experts.

Conclusion 3: The use of a previous knowledge engineering experiment, that mimics computer interaction by having several domain experts act as the expert system while another domain expert acts as the novice user of the expert system, was applied successfully during the MARS knowledge

engineering effort. The simulation of the interaction between an expert system and a novice user proved to be highly beneficial in focusing the questions and answers suggested by the developmental experts for an asset reconciliation computation.

Conclusion 4: A conclusion in the study being validated stated, "multiple experts should be used to discover the heuristics for complex cases", this conclusion was definitely applicable to the MARS knowledge engineering effort. The range of opinions and ideas offered by multiple experts is needed to account for the special cases and unique situational factors that can occur during case analysis.

Research Question 3: Can the rules needed to perform an asset reconciliation be encoded using the Teknowledge M.1 software program?

Conclusion 5: The Teknowledge M.1 software program was capable of incorporating the rules needed to perform the limited task of asset reconciliation. The expert system prototype which was developed, the Manager's Asset Reconciliation System (MARS) contained 150 rules and demonstrated the capability of reconciling numerous types of assets under a range of circumstances. The increased effectiveness of item managers using MARS demonstrated their greater understanding of the asset reconciliation process. The Teknowledge M.1 software program was proven to be

capable of encoding the required rules and facts needed for the asset reconciliation task.

Domain expert critiques of MARS, both verbal and written, suggested modifications for the expert system. A 'fast version' of the system which bypasses much of the advice offered by the MARS prototype was suggested. The assumption could be made that a quicker consultation would be an important benefit in convincing potential users of the system's worth. The 'fast version' would, theoretically, be for knowledgeable item managers who do not require a full explanation of all the steps in the asset reconciliation process. The capability of choosing either a fast version, slow version, or some combination of the two could reduce the consultation time of the system dramatically. However, the choice to bypass information might also reduce the effectiveness of the system by allowing users to make more errors. The M.1 software program can incorporate the variable versions of MARS suggested.

Storing historical data in the expert system was another suggested modification to MARS. Storing past quarters of relevant item information will speed up the asset reconciliation process. A reduction in computational errors is assumed due to the elimination of data transferal errors and simple mathematical errors. The suggested modification can be achieved by loading the historical data into the memory of MARS.



The need for a greater capability to change asset quantities once they are entered in MARS was another suggestion offered by the domain experts. The current limited correction capability of MARS can be improved by the modification of current rules in MARS and by the inclusion of additional rules. The M.1 software package is capable of incorporating the modifications and additions required to comply with all the improvements suggested in the test subjects critiques.

Conclusion 6: The development of an expert system does not necessarily require extensive time and large monetary outlays. The implementation of expert systems using relatively low-cost microcomputers appears to be a viable option in the Materiel Management arena of operations. The initial prototype was developed in only three months using the M.1 software program hosted on a microcomputer. The development of the MARS prototype cost approximately \$10,000. This rough approximation includes travel and manpower expenses for the developmental experts, the knowledge engineer, and other personnel associated with the project. The expense of a microcomputer, the M.1 software program, and a printer were considered sunk costs and were not included in the cost approximation.

Research Question 4: How does the developed expert system prototype affect the productivity of the using organization?

Research Question 4 was divided into three specific questions. The first being: Does the use of the expert system increase effectiveness by at least 15%?

Conclusion 7: A 19.45 percent overall improvement in the effectiveness of those item managers assisted by MARS seems to suggest that savings could be realized if MARS was implemented. A 5 percent improvement in the effectiveness scores of item managers tested with the simple case was achieved. A simple case is one that is frequently encountered and has fewer possible dimensions in the decision-making scenario than a complex case. Even a 5 percent improvement in the effectiveness of managing assets could be transformed into substantial savings. The MARS prototype demonstrated a 37.92 percent improvement in the effectiveness scores of those item managers tested with the complex case. The large gain in effectiveness suggests that MARS has the potential of improving inventory management procedures and saving the Government considerable financial resources.

The first test run of MARS against a completed AFLC Form 47, which had been thoroughly checked for accuracy by several item managers beforehand, discovered the reconciled asset quantity to be seven items in error. The inaccuracy was a misrepresentation of inventory assets equalling nearly \$20,000. The enhanced management of inventory items not only reduces the cost of carrying

inventory but also improves the overall readiness of the Air Force by improving the accuracy of a logistics support function. Mismanagement of inventory results in procuring items the Government does not require; not procuring items the Government does require; terminating items before or after the items should be terminated; and disposing of items before or after the items should have been disposed. MARS should be further developed and tested because of the system's tremendous potential for improving the inventory management process and saving the government money.

The second performance question: Does the use of the expert system reduce the time required by the item manager to complete an asset reconciliation?

Conclusion 8: The research findings revealed that item managers assisted by the expert system took 10.67 minutes longer overall to complete both the complex test case and the simple test case. The poor performance is attributed, in part, to the inflexibility of the system consultation. MARS did not allow the users to freely scroll back and forth to whatever section of the Form 47 they wished to address during the consultation. 'Backtracking' capabilities were available at various points throughout the program but the lack of user familiarity with the expert system reduced the effectiveness of this program feature. The limited capability to make changes after item quantities were entered and the relatively advanced wording of questions presented

by the expert system were also drawbacks to the system/user efficiency level.

Subjects tested were only given a five to ten minute introduction regarding expert system consultations. The introduction involved a step by step process through the first few questions of an example case. Therefore, virtually all of the questions presented to the subject during the test case were seen by the subject for the very first time. The subjects lack of familiarity with the MARS system is assumed to have affected efficiency negatively.

Conclusion 9: Training of item managers in computer procedures and expert system operations will increase the efficiency of future expert system applications. A major contributor to the reduction in the efficiency of MARS was assumed to be the computer skill level of the item managers. The self reported computer experience and computer confidence of the items managers that participated in the testing was quite low. Sixty-seven percent of the subjects tested reported either no computer experience or limited computer experience. Sixty-one percent of the subjects tested described themselves as having either no confidence or limited confidence regarding computer useage.

Two individuals were afforded the opportunity of exposure to MARS before using the system for completion of an asset reconciliation test case. Both of these individuals received 100 points for their effectiveness scores;

additionally, one of these individual recorded the fastest time to completion for her journeyman item manager group, while the other individual recorded an above average time to completion for her novice item manager group. These results suggest the possibility of considerable efficiency gains after the expert system training of item managers is accomplished.

The third performance related question was subjective in nature: What is the user's subjective evaluation of the assistance provided by the expert system for asset reconciliation?

Conclusion 10: The test subjects thought MARS was a good system with tremendous potential for improving how item managers perform the asset reconciliation function. The test subject critiques of the system demonstrated positive feedback and are included in Appendix L. The written and oral critiques offered by the Materiel Management personnel at WR-ALC seem to suggest that there is a real need for the system. The importance of user acceptance was stressed throughout the literature reviewed for this research project. The apparent level of user acceptance of MARS was high. The positive critiques suggest that the implementation of such a system has a strong chance for success if properly introduced, expanded, and maintained.

Research Question 5: How significant is experience level in determining the performance level of item managers

assisted by the expert system? Does use of the expert system help less experienced item managers more than experienced item managers?

Conclusion 11: The experience level of the item managers seemed to have an impact on the change in effectiveness caused by the MARS prototype. The experience by method interaction for effectiveness was not found to be significant. The researcher expected the novice group of item managers to benefit the most from MARS, followed by the journeyman group, with the advanced group of item managers benefiting the least. The actual findings, although not significant, did not conform to this presupposed pattern of increased benefit as the experience levels decreased. The actual test results demonstrated the amount of improvement varied considerably within experience groups between the simple and complex cases.

The advanced item managers improved their effectiveness scores when using MARS by 41.25 percent on the complex case and 8.88 percent on the simple case for an overall increase in effectiveness of 18.62 percent. Journeyman item managers improved their effectiveness when assisted by MARS 46.87 percent on the complex case and 14.45 percent on the simple case for an overall increase in effectiveness of 29.66 percent. Novice item managers improved their effectiveness scores by 22.76 percent on the complex case and actually reduced their effectiveness scores by 12.50

percent on the simple case for an overall increase in effectiveness of 6.32 percent. These findings suggest MARS was too complicated for the novice item manager to gain the full benefit of the knowledge encoded in the expert system. To make MARS better suited for novice item managers, more detailed descriptions of where to find the information needed to perform an asset reconciliation should be included in the MARS consultation program. The use of 'novice' language, i.e. simplified wording, for the consultation should improve the value of MARS greatly.

Table 17

Mean Total Effectiveness Scores, Experience by Method

Solution Method	Experience Level			
	Novice	Journeyman	Advanced	All Levels
Manual	61.53 (13)	41.17 (17)	66.67 (15)	55.55 (45)
Expert System	67.85 (14)	70.83 (18)	85.29 (17)	75.00 (49)
Both Solutions	64.81 (27)	56.43 (35)	75.56 (32)	65.69 (94)

The large increase in the effectiveness of the journeyman category is attributed to the following:

1. The language of MARS, i.e. the wording of the consultation questions, proved to be difficult for the novice item manager to interpret but was not too difficult for the journeyman item manager.

2. The journeyman item managers had more room for improvement than the more proficient advanced item manager.

Conclusion 12: The experience level of the item managers had a significant affect on the change in efficiency of those item managers assisted by the MARS prototype. The experience by method interaction for efficiency was found to be significant. The researcher did not expect any increases in efficiency to be achieved by item managers assisted by MARS because of their lack of familiarity with computer operation and the expert system. If an efficiency improvement were to be observed, the researcher assumed the time to completion of the novice group of item managers would be reduced the most when they were assisted by MARS. The researcher also assumed that the time required to complete a test case by the advanced group of item managers would be affected the least when assisted by MARS. The findings described in Chapter IV did not support these contentions. Efficiency score findings demonstrated that MARS improved the efficiency of advanced item managers on complex cases while all other treatment



combination times to completion were increased. The advanced item managers actually reduced their average time to completion by 4.75 minutes when assisted by MARS on the complex test case. The largest increase in the amount of time required to complete a test case occurred when the novice group was assisted by MARS on the simple case. The novice group average time to completion for the simple case was increased from 22.5 minutes to 43.3 minutes when they were assisted by MARS. These findings seem to support the contention that the wording of the questions posed by MARS was set at too high a level and should be reworded to be more easily understood by novice item managers. Several changes to simplify the system are already being implemented by this researcher. Once the modifications to MARS are completed the system should be of considerably more value to novice item managers in their daily work activities and should also be useful for training.

Conclusion 13: Substantial novice input should be included in the development of future expert system applications. The results of the experience by method analysis and the review of test subject critiques suggest that greater novice input during prototype development should broaden the group of users that can successfully use the expert system. Required actions that appear obvious to an expert might be ignored during the knowledge engineering process without the input of a less experienced novice.

### Recommendations for Future Research

The use of expert system technology to improve inventory management operations includes a wide range of topics to be considered for further study. Three suggestions for future research include the development and evaluation of new expert systems, the implementation and maintenance of expert systems, and the extension of studies regarding MARS.

The inventory management function offers a wide range of tasks for which an expert system could be developed. For example, the Air Force Logistics Command (AFLC) is in the process of developing 12 major, integrated, information systems under the Logistics Management Systems (LMS) Modernization Program. Research could be conducted to develop and measure the impact of an expert system that supports the interaction of users with any of the new LMS Modernization Programs, i.e. the Requirements Data Bank (RDB) or the Stock Control and Distribution system (SC & D). Such an expert system would assist the user in accessing the information system, interpreting the accessed data, and applying the data in a productive manner. The application of expert systems to support the user interface with LMS is an area of research that offers tremendous potential returns.

Considerable research has yet to be accomplished regarding the implementation and maintenance of expert systems. Post developmental issues are extremely important

to the overall success of any new system. Research could reveal which procedures result in the most successful introduction of an expert system and which element of the using organization should be responsible for the maintenance of the expert system once the system is in place. For example, should the developed expert system be introduced by the developer or by someone in a leadership role in the using organization? Should the user's themselves be responsible for maintenance of the expert system or should the responsibility for upkeep be assumed by a centralized department within the organization?

Another area of possible investigation involves the extension of the MARS study, for example, further performance measurement of MARS. The evaluation of item managers assisted by MARS should be conducted at ALC's other than Warner Robins ALC in order to determine if MARS can be applied productively by item managers throughout the Air Force Logistics Command. The evaluation of item managers who have had adequate practice in the use of MARS prior to testing should also be conducted. Development of an advanced version of MARS which includes other item manager functions could be attempted. The development of this advanced version could be accomplished using 50 percent novice item managers and 50 percent advanced item managers in an attempt to determine the most appropriate mix of experience required for expert system developmental

personnel. MARS could be further developed to include the capability of automatically accessing all the required data to compute a Form 47 needing human interaction only for predetermined exceptional cases. Further analysis of the affects of computer experience and computer confidence on expert system performance could also be attempted. Following the modification and upgrade of MARS, item manager performance should be measured again to determine the impact of the modifications on the effectiveness and efficiency of item managers assisted by MARS.

Expert systems will have a tremendous influence upon logistics operations in the future. Considerable research still needs to be done in support of expert system application to logistics management functions. The research conducted broadened the base of knowledge regarding expert system applications and demonstrated the promise of expert system technology in the field of materiel management.

## Appendix A: Definitions

Artificial intelligence - The part of computer science concerned with developing intelligent computer programs [51:10].

Backward-chaining, Backchaining - A reasoning strategy produced by the combination of rule-based representation, modus ponens inference, and goal-directed control. In this strategy, a chain of inferences is constructed starting with a rule whose conclusion would immediately provide a solution to the problem (the goal). Then the system works backward, setting up the premise clauses of the rule as subgoals. Other rules whose conclusions could satisfy these subgoals are then invoked, and their premises also become subgoals. The process continues working backward until rules are reached whose premises can be verified directly. In an exhaustive backward-chaining system, all possible rules are examined to arrive at a result [45:G-2].

Case - A particular problem for which a knowledge system can perform its task. For example, a car diagnosis system might find the cause of a charging problem in Frank Smith's Chevrolet. Cases are used to develop, expand, and evaluate the performance of knowledge systems [45:G-3].

Domain - A field, discipline, or area of human activity or scholarship such as mathematics, medicine, physics, auto mechanics, etc. Existing knowledge systems perform specialized tasks within domains. No system yet offers advice about an entire domain [45:G-5].

Domain expert - A person who through years of training and experience has become extremely proficient at problem solving in a particular domain [51:10].

End-user - The person who uses the finished expert system; the person for whom the system was developed [51:10].

End-User System - A knowledge system that helps or advises a user in a way that parallels the way a human consultant advises a client. The knowledge system may ask questions of the user to gather information from which to infer appropriate advice. Some consultation systems (including knowledge systems developed using M.I) are able to explain their reasoning so that the user can judge its reliability [45:G-6].

Expert - A human who can solve problems or perform actions requiring unusual or uncommon skill. The expert's skills are likely to have evolved slowly, and usually require extensive knowledge and lengthy experience [45:G-6].

Expertise - The set of capabilities that underlies the high performance of human experts, including extensive domain knowledge, and compiled forms of behavior that afford great economy in skilled performance. Expert knowledge is rare, seldom explicit or measurable, and difficult to communicate or acquire. Gained through experience, long periods of training, apprenticeship and observation, it may be organized in subtle and idiosyncratic ways [45:G-6].

Expert system - A computer program using expert knowledge to attain high levels of performance in a narrow problem area [51:11]. A knowledge system that performs at or near the level of human experts. The system achieves high levels of performance on tasks that, for human beings, require years of special education and training. Often the use of this term is synonymous with knowledge system. However, we make the distinction that an expert system is a special kind of knowledge system, one that uses knowledge acquired from an expert rather than from other sources [45:G-6].

Goal - The result or achievement toward which effort is directed. In M.I., a goal is an expression for which a value is being sought. The goals of a consultation are declared in an M.I. knowledge base using the goal meta-fact [45:G-8].

Heuristic - A rule of thumb or simplification that limits the search for solutions in domains that are difficult and poorly understood [51:22].

Inference - The process of deriving new facts from known ones. The method of inference defines the one-step derivations that are legal with respect to a given representation in a knowledge system. Examples of inference methods are modus ponens and inheritance. Together with representation and control, inference is one of the three dimensions of a knowledge system [45:G-9].

Inference engine - That part of a knowledge-based system or expert system that contains the general problem-solving knowledge [51:22].

Knowledge - Propositions and heuristic rules. Those kinds of data that can improve the efficiency or effectiveness of a problem solver. Types of dimensions such as: symbolic vs numeric, factual vs heuristic, imperative vs declarative, deep vs shallow [45:G-10].

Knowledge Acquisition - The extraction and representation of knowledge derived from current sources, especially from experts. The activity of transferring or transforming the knowledge and skills from a human expert or other knowledge source into a form usable by a knowledge system. Knowledge acquisition often involves chunking or parsing an expert's knowledge into a collection of if-then rules [45:G-10].

Knowledge-based system - A program in which the domain knowledge is explicit and separate from the program's other knowledge [51:23].

Knowledge base - The portion of a knowledge-based system or expert system that contains the domain knowledge [51:23].

Modus Ponens - A rule of inference that states: If A then B is true, and A is true, you can infer that B is true [45:G-12].

Natural language - The standard method of exchanging information between people, such as English (to be contrasted with artificial languages, such as programming languages) [51:78].

Rule - A formal way of specifying a recommendation, directive, or strategy, expressed as IF premise THEN conclusion or IF condition THEN action [51-23].

User - A person who uses an expert system, such as an end-user, a domain expert, a knowledge engineer, a tool builder, or a clerical staff member [51:11].

User Interface - One subsystem of a knowledge system (or any computing system) with which the human user deals routinely. It aims to be as 'natural' as possible, employing language as close as possible to ordinary language (or the stylized language of a given field) and understanding and displaying images, all at speeds that are comfortable and natural for humans. Other subsystems in a knowledge system are the knowledge base and the inference engine [45:G-17].

Appendix B: Knowledge Engineering Exercise One

EXERCISE ONE

Please answer the following questions. Be as specific as possible. Read all the questions before answering.

1. Define Asset Reconciliation in general terms.
2. What do you consider the most difficult part of the Asset Reconciliation process?
3. What is the most common mistake made in the Asset Reconciliation process?
4. Do certain assets require significantly different procedures during Asset Reconciliation? If so, what types of assets and how are the procedures different?
5. What is the objective of completing AFLC Form 47?



Appendix C: Knowledge Engineering Exercise Two

EXERCISE TWO

For each of the selected cases, conduct an asset reconciliation computation in accordance with the following instructions.

Be very specific and very detailed. Write out how you would complete the computation (e.g., first ....., next .....). Number each step. Indicate where you find the information required for the computation.

Please try to explicitly list all the detailed intermediate steps you go through.

Appendix D: Knowledge Engineering Exercise Three

EXERCISE THREE

This exercise involves role-playing. One of you will be asked to act as the expert system while the other person will act as the novice item manager. Imagine a computer screen separates you from the other person.

The person acting as the novice will attempt to complete the selected asset reconciliation case using the advice and suggestions of the person acting as the expert system.

If you are acting as the expert system, please do not use your hands to point or gesture in any way. If you are acting as the novice, please respond to the suggestions offered by the other person as a novice item manager would.

Appendix E: Testing Facility Requirements and the  
Schedule for Testing

EVALUATION REQUIREMENTS FOR  
THE MANAGER'S ASSET RECONCILIATION SYSTEM (MARS)

1. Testing area with ten IBM compatible computers (Z-248s). There should be enough space around the computers for regulations, documentation, etc.
2. In advance of actual testing, participants should be identified and scheduled for testing on the 22, 23, 24, of June.
  - a. A range of participant experience is needed.
    - 1) novice - less than one year of experience as an item manager
    - 2) journeyman - one to four years of experience as an item manager
    - 3) advanced - more that four years of experience as an item manager
3. Participants should be scheduled ten at a time, for one-hour and fifteen minute intervals, with 15 minute 'break periods between each testing session. Participants should be told to bring any items which they might normally use to complete a Form 47 (regulations, a caluculator, etc.).
4. Option One (Preferred):  
Need 40 novice item managers.  
Need 40 journeyman item managers.  
Need 40 advanced item managers.  
  
Option Two:  
Need 40 novice item managers.  
Need 40 'other' item managers.  
Other - more than one year of experience as an item manger.

Note: All test results will remain anonymous.

Appendix F: Written Directions Provided to Test Subjects

DIRECTIONS PROVIDED TO TEST  
SUBJECTS WHO WERE ASSISTED BY  
THE EXPERT SYSTEM

The purpose of this exercise is to field test the Manager's Asset Reconciliation System (MARS). MARS was developed to assist item managers with the asset reconciliation computation. This test is designed to determine if item managers do a better job of asset reconciliation when assisted by MARS.

You have been randomly preassigned to reconcile a case with the assistance of MARS. MARS' performance in advising you on the reconciliation of this case will be graded in accordance with answers predetermined by a panel of experts. The case you reconcile will receive a grade between 0 and 100 points. Your MARS-assisted performance will be compared with the performance of item managers who reconcile this same case without the assistance of MARS.

At this time, please complete the questionnaire entitled SUBJECT INFORMATION. When you are finished, await further instructions. Do Not begin the case until told to do so.

An introductory case has been provided so that you may learn to use MARS. You will reconcile this case first. MARS will ask you a series of questions about your computation and the supporting documentation. MARS asks very specific questions. Please read the questions carefully and accurately answer the questions which MARS asks.

You answer by typing the correct answer and depressing the ENTER key. You do not need to type the complete response. Usually the first letter of the response is sufficient for MARS to distinguish your answer. For example, if MARS asks you a yes/no question, you would answer yes by typing "y" and depressing the ENTER key.

Based upon your responses, MARS will provide advice on the correct quantity of assets for your Form 47. If you have any questions, raise your hand. One of the test administrators will assist you.

Upon completion of the introductory session, you will be provided the test case on which MARS' performance will be measured. One of the test administrators will give a brief description of the test case, then you may begin. When you finish this case, please provide your feedback by completing the page entitled MARS CRITIQUE. Then you may leave. Please leave quietly as others may still be working.

Please comply with the following rules:

1. Do not write in the case folder. Use the back of your questionnaire if you need to make notes.
2. Do not talk with anyone about this case or what you believe to be the correct answers.
3. You may ask questions only of a test administrator. To do so, raise your hand.
4. Do not talk with anyone else in the room or make any comments aloud.
5. Do not worry about others finishing before you. Performance in terms of the reconciled asset quantity is the primary concern. Time should not be considered as a factor.
6. Do not put your name on any of the forms. This exercise is anonymous.
7. Remember to complete all the required entries for the asset reconciliation computation.
8. A test administrator will verify that all entries on the questionnaires are complete before you leave.
9. Please do not remove anything from this room. If you took notes on the case, you must turn them in to an administrator with your questionnaires.

DIRECTIONS PROVIDED TO TEST  
SUBJECTS WHO WERE NOT ASSISTED  
BY THE EXPERT SYSTEM

The purpose of this exercise is to field test the Manager's Asset Reconciliation System (MARS). MARS was developed to assist item managers with the asset reconciliation computation. This test is designed to determine if item managers do a better job of asset reconciliation when assisted by MARS.

You have been randomly preassigned to reconcile a case without the assistance of MARS (manually). Your performance in reconciling this case will be graded in accordance with answers predetermined by a panel of experts. The case you reconcile will receive a grade between 0 and 100 points. Your performance will be compared with the performance of item managers who reconcile this same case with the assistance of MARS.

At this time, please complete the questionnaire entitled SUBJECT INFORMATION. When you are finished, await further instructions. Do Not begin the case until told to do so.

You will be provided the test case on which your performance will be measured. One of the test administrators will give a brief description of the test case, then you may begin. If you have any questions, please raise your hand. One of the test administrators will assist

you. When you finish this case, please leave quietly as others may still be working.

Please comply with the following rules:

1. Do not write in the case folder. Use the back of your questionnaire if you need to make notes.
2. Do not talk with anyone about this case or what you believe to be the correct answers.
3. You may ask questions only of a test administrator. To do so, raise your hand.
4. Do not talk with anyone else in the room or make any comments aloud.
5. Do not worry about others finishing before you. Performance in terms of the reconciled asset quantity is the primary concern. Time should not be considered as a factor.
6. Do not put your name on any of the forms. This exercise is anonymous.
7. Remember to complete all the required entries for the asset reconciliation computation.
8. A test administrator will verify that all entries on the questionnaires are complete before you leave.
9. Please do not remove anything from this room. If you took notes on the case, you must turn them in to an administrator with your questionnaires.



Appendix G: Questionnaire Completed by Test Subjects

SUBJECT INFORMATION

Please answer the following questions:

1. I have been a D041 item manager for \_\_\_\_\_ years.
2. I am performing case number \_\_\_\_\_ .
3. I am doing this case (check one)  
\_\_\_\_\_ manually  
\_\_\_\_\_ with the expert system
4. I would rate my experience in interacting with a computer as: (check one)  
\_\_\_\_\_ No experience at all  
\_\_\_\_\_ Limited experience  
\_\_\_\_\_ Mediocre  
\_\_\_\_\_ Experienced  
\_\_\_\_\_ Very experienced
5. I would rate my confidence in interacting with a personal computer as: (check one)  
\_\_\_\_\_ No confidence  
\_\_\_\_\_ Limited confidence  
\_\_\_\_\_ Mediocre  
\_\_\_\_\_ High  
\_\_\_\_\_ Very high

Appendix H: Supporting Documentation for the Complex  
Asset Reconciliation Test Case

15 April 87

1610-00-071-5472

D165 Tight Item Report dated 15 Apr 87 reports 65 total assets on hand. 31 Mar 87 SB & CR reported 30 assets. Form 47 increased by 35 for Mar 87 cycle.

NATIONAL STOCK NUMBER 160-02-071-5472 24-1612-02-873-6438	ITEM ACTIVITY CODE C8	AS OF DATE 31 Dec 85	AS OF DATE 31 Dec 86	AS OF DATE 31 Dec 86
1. TOTAL ACQUIRED ASSETS		687	687	687
2. STARTING POSITION (Date:)	30 June 84	462	462	462
3. ASSET LOSSES				
Condemnations		61	125	168
Mock-ups				
Installations/SPRAM		18	32	32
On-loan (Self-managed)				
Test Equipment				
Shipments to FMS/SA Programs		2	2	2
Shipments to Non-Reporting Activities				1
Special Projects				
Modifications				
Minus IAV		1	1	1
Transfers to R&M				
Other (Explain in Remarks)				
TOTAL (ASSET LOSSES)		82	160	204
4. ASSET GAINS				
Plus IAV				2
Modification				
Other (Explain in Remarks)				
TOTAL (ASSET GAINS)				2
5. BALANCE ACCOUNTABLE ASSETS		380	302	260
6. DUE-IN ASSETS				
On order PR/MIPR (funded)				
On order contract				
Unfunded PR (Information Entry)	70-4			(150)
ISSP				
Reclamation				
Contract Termination				
Other (Explain in Remarks)				
TOTAL (DUE IN ASSETS)				
7. NET BALANCE ACCOUNTABLE		380	302	260
8. CURRENT SB & CR ASSETS				
Serviceables (Include DIRM)				
Unserviceables				
Intermitt (Serviceable)				
Intermitt (Unserviceable)				
WRM (Serviceable)				
DROM				
Other				
TOTAL (CURRENT SB & CR ASSETS)		398	315	270
9. DOTM (Included in Block 8)		4	11	7
10. NET SB & CR ASSETS (Block 8 Block 9)		394	308	263
11. DIFFERENCE (Block 10 - vs Block 10)		+14	+6	+3
12. ADJUSTMENT TO REPORTED ASSETS AFTER RESEARCH		-13	0	-3
13. NET DIFFERENCE (BLOCK 11 + / - BLOCK 12)		+1	+6	0
14. PERCENTAGE OF NET DIFFERENCE (BLOCK 13 - BLOCK 7)		-0.270	+2.00	0
15. ON HAND ASSETS USED IN COMPUTATION		385	309	267

14. REMARKS (Continue on reverse)

MARKS (Continue on reverse)

Dec 85 - Line 3 minor 1AV 1ea 5325 day FD206553179999

Line 12 - Improper maintenance transaction caused assets to be overstated.

Line 13 1 each Fair asset for repair/replace (add, time in camp)

Doc 86. Line 12: Improper drawdown of Beach By Shop on  
MNPP9M 63044208 overstated LWR review.

**AFLC FORM 47**  
OCT 63

**PREVIOUS EDITION IS OBSOLETE**

Ab6 assets.

[illegible]

PROD. DIST. NUMBER AND TYPE	DATE	QUANTITY	DATE	TIME	PRICE	UNIT PRICE	TOTAL PRICE	DATE	TIME	PRICE	UNIT PRICE	TOTAL PRICE	DATE	TIME	PRICE	UNIT PRICE	TOTAL PRICE
WGR-18857	1	29	1/16/46				7530										
WGR-24149	1	66	1/17/46				73030										
<p>Production was in progress at Vintners' plant and the agreement          could not be completed and was cancelled. WGR-24149          Extra, agreement. WGR-18857, 18858, 18859, 18860, 18861, 18862, 18863, 18864, 18865, 18866, 18867, 18868, 18869, 18870, 18871, 18872, 18873, 18874, 18875, 18876, 18877, 18878, 18879, 18880, 18881, 18882, 18883, 18884, 18885, 18886, 18887, 18888, 18889, 18890, 18891, 18892, 18893, 18894, 18895, 18896, 18897, 18898, 18899, 18900, 18901, 18902, 18903, 18904, 18905, 18906, 18907, 18908, 18909, 18910, 18911, 18912, 18913, 18914, 18915, 18916, 18917, 18918, 18919, 18920, 18921, 18922, 18923, 18924, 18925, 18926, 18927, 18928, 18929, 18930, 18931, 18932, 18933, 18934, 18935, 18936, 18937, 18938, 18939, 18940, 18941, 18942, 18943, 18944, 18945, 18946, 18947, 18948, 18949, 18950, 18951, 18952, 18953, 18954, 18955, 18956, 18957, 18958, 18959, 18960, 18961, 18962, 18963, 18964, 18965, 18966, 18967, 18968, 18969, 18970, 18971, 18972, 18973, 18974, 18975, 18976, 18977, 18978, 18979, 18980, 18981, 18982, 18983, 18984, 18985, 18986, 18987, 18988, 18989, 18990, 18991, 18992, 18993, 18994, 18995, 18996, 18997, 18998, 18999, 19000, 19001, 19002, 19003, 19004, 19005, 19006, 19007, 19008, 19009, 19010, 19011, 19012, 19013, 19014, 19015, 19016, 19017, 19018, 19019, 19020, 19021, 19022, 19023, 19024, 19025, 19026, 19027, 19028, 19029, 19030, 19031, 19032, 19033, 19034, 19035, 19036, 19037, 19038, 19039, 19040, 19041, 19042, 19043, 19044, 19045, 19046, 19047, 19048, 19049, 19050, 19051, 19052, 19053, 19054, 19055, 19056, 19057, 19058, 19059, 19060, 19061, 19062, 19063, 19064, 19065, 19066, 19067, 19068, 19069, 19070, 19071, 19072, 19073, 19074, 19075, 19076, 19077, 19078, 19079, 19080, 19081, 19082, 19083, 19084, 19085, 19086, 19087, 19088, 19089, 19090, 19091, 19092, 19093, 19094, 19095, 19096, 19097, 19098, 19099, 19100, 19101, 19102, 19103, 19104, 19105, 19106, 19107, 19108, 19109, 19110, 19111, 19112, 19113, 19114, 19115, 19116, 19117, 19118, 19119, 19120, 19121, 19122, 19123, 19124, 19125, 19126, 19127, 19128, 19129, 19130, 19131, 19132, 19133, 19134, 19135, 19136, 19137, 19138, 19139, 19140, 19141, 19142, 19143, 19144, 19145, 19146, 19147, 19148, 19149, 19150, 19151, 19152, 19153, 19154, 19155, 19156, 19157, 19158, 19159, 19160, 19161, 19162, 19163, 19164, 19165, 19166, 19167, 19168, 19169, 19170, 19171, 19172, 19173, 19174, 19175, 19176, 19177, 19178, 19179, 19180, 19181, 19182, 19183, 19184, 19185, 19186, 19187, 19188, 19189, 19190, 19191, 19192, 19193, 19194, 19195, 19196, 19197, 19198, 19199, 19200, 19201, 19202, 19203, 19204, 19205, 19206, 19207, 19208, 19209, 19210, 19211, 19212, 19213, 19214, 19215, 19216, 19217, 19218, 19219, 19220, 19221, 19222, 19223, 19224, 19225, 19226, 19227, 19228, 19229, 19230, 19231, 19232, 19233, 19234, 19235, 19236, 19237, 19238, 19239, 19240, 19241, 19242, 19243, 19244, 19245, 19246, 19247, 19248, 19249, 19250, 19251, 19252, 19253, 19254, 19255, 19256, 19257, 19258, 19259, 19260, 19261, 19262, 19263, 19264, 19265, 19266, 19267, 19268, 19269, 19270, 19271, 19272, 19273, 19274, 19275, 19276, 19277, 19278, 19279, 19280, 19281, 19282, 19283, 19284, 19285, 19286, 19287, 19288, 19289, 19290, 19291, 19292, 19293, 19294, 19295, 19296, 19297, 19298, 19299, 19300, 19301, 19302, 19303, 19304, 19305, 19306, 19307, 19308, 19309, 19310, 19311, 19312, 19313, 19314, 19315, 19316, 19317, 19318, 19319, 19320, 19321, 19322, 19323, 19324, 19325, 19326, 19327, 19328, 19329, 19330, 19331, 19332, 19333, 19334, 19335, 19336, 19337, 19338, 19339, 19340, 19341, 19342, 19343, 19344, 19345, 19346, 19347</p>																	











AS OF 31 MAR 87

IM QUARTERLY WORLDWIDE ASSETS AND LEVELS REPORT

PCN: A-D104-FF1-01-MFF

RUN DATE 18 APR 87

FSC 1610

MANAGER 2NV

SUB GROUP MASTER NSN	E R	AC CO	CD CD	C UI	SRAN	TE	SERV BAL	UNSERV BAL	DIFM BAL	WRM BAL	WRM DEMAND LVL	REOSN OBJ	DOTM BAL	TOC BAL	DUE IN FM O/H	FLOAT STK	SPRAM LVL	BAL
1610000715472	T	EA	F86043	01			1	0	0	2	3	0	3	0	0	0	0	0
1610000715472	T	EA	F86081	01			0	0	0	0	4	0	4	0	0	0	0	0
1610000736423	T	EA	F86081	01			0	0	0	1	0	1	1	0	0	0	0	0
SRAN TOTAL							0	0	0	1	4	1	5	0	0	0	0	0
1610000715472	T	EA	F86102	01			0	0	0	3	4	0	4	0	0	0	0	0
1610000736423	T	EA	F86102	01			1	0	0	0	0	0	2	0	0	0	0	0
SRAN TOTAL							1	0	0	4	4	0	6	0	0	0	0	0
1610000715472	T	EA	F86191	01			0	0	0	2	3	0	3	0	0	0	0	0
1610000715472	T	EA	F86221	01			0	0	0	2	3	0	3	0	0	0	0	0
1610000736423	T	EA	F86221	01			0	0	0	0	0	1	1	0	0	0	0	0
SRAN TOTAL							0	0	0	2	3	1	4	0	0	0	0	0
1610000715472	T	EA	F86231	01			1	0	0	4	4	0	4	0	0	0	0	0
1610000715472	T	EA	F86252	01			1	0	0	4	4	0	6	0	0	0	0	0
1610000715472	T	EA	F86323	01			1	0	0	4	4	0	4	0	0	0	0	0
1610000715472	T	EA	F86325	01			2	0	0	1	1	0	6	0	0	0	0	0
1610000715472	T	EA	F86331	01			1	0	0	1	3	0	6	0	0	0	0	0
1610000736423	T	EA	F86331	01			1	0	0	1	0	0	0	0	0	0	0	0
SRAN TOTAL							2	0	0	2	3	0	6	0	0	0	0	0
1610000715472	T	EA	F86353	01			0	0	0	2	3	0	3	0	0	0	0	0
1610000736423	T	EA	F86353	01			0	0	0	0	0	0	4	0	0	0	0	0
SRAN TOTAL							0	0	0	2	3	0	7	0	0	0	0	0
1610000715472	T	EA	F86356	01			0	0	0	2	2	0	3	0	0	0	0	0
1610000715472	T	EA	F86371	01			0	0	0	0	2	0	2	0	0	0	0	0

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PCN: A-D104 -FF1-01-MFF

## IM QUARTERLY WORLDWIDE ASSETS AND LEVELS REPORT

AS OF 31 MAR 87

MANAGER		2MV	FSC		RUN DATE		16 APR 87	
SUB GROUP		AC	CO		TE		SRAN	
MASTER NSN		UI	SRAN		TE		SRAN	
CURRENT NSN		UI	SRAN		TE		SRAN	
1610000715472		EA	F84810		01	0	0	0
1610000736423		EA	F84810		01	0	0	0
SRAN TOTAL						0	0	0
1610000715472		EA	F84829		01	0	0	0
1610000715472		EA	F84877		01	0	0	0
1610000736423		EA	F84877		01	0	0	0
SRAN TOTAL						0	0	0
1610000715472		EA	F85000		01	3	0	0
1610000736423		EA	F85000		01	3	0	0
SRAN TOTAL						3	0	0
1610000715472		EA	F85209		01	0	0	0
1610000736423		EA	F85209		01	0	0	0
SRAN TOTAL						0	0	0
1610000715472		EA	F85250		01	2	0	0
1610000736423		EA	F85250		01	2	0	0
SRAN TOTAL						2	0	0
1610000715472		EA	F85260		01	3	0	0
1610000736423		EA	F85270		01	0	0	0
SRAN TOTAL						3	0	0
1610000715472		EA	F85518		01	0	0	0
1610000736423		EA	F85518		01	0	0	0
SRAN TOTAL						0	0	0
1610000715472		EA	F85804		01	0	0	0
1610000715472		EA	F85844		01	0	0	0
1610000736423		EA	F85644		01	0	0	0
SRAN TOTAL						0	0	0
1610000715472		EA	F86041		01	0	0	0

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AS OF 31 MAR 87

IM QUARTERLY WORLDWIDE ASSETS AND LEVELS REPORT

PCN: A-DIOA--FF1-Q1-MEF

RUN DATE 16 APR 87

FSC 1610

MANAGER 2MV

SUB GROUP MASTER NSN CURRENT NSN	E R C	UI	SRAN	TE	AC CD CD	SERV BAL	UNSERV BAL	DIFM BAL	WRM BAL	WRM LVL	DEMAND LVL	REQSN OBJ	DOTM BAL	IOC BAL	DUE IN PM O/H	FLOAT STK	SPRAM LVL	BAL
1610000715472																		
1610000715472	T	EA	F82027	O1		0	0	0	0	0	0	1	0	0	0	0	0	0
1610000715472	T	EA	F82047	O1		0	0	0	1	1	0	2	0	0	0	0	0	0
1610008736423	T	EA	F82047	O1		1	0	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL						1	0	0	1	1	0	2	0	0	0	0	0	0
1610000715472	T	EA	F82059	OA		0	0	1	0	0	1	1	0	0	0	0	0	0
1610000715472	T	EA	F82065	O9		1	11	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	F82065	OA		0	0	0	0	0	3	3	0	0	0	0	0	0
1610008736423	T	EA	F82065	O9		1	5	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL						2	16	0	0	0	3	3	0	0	0	0	0	0
1610000715472	T	EA	F82400	O1		0	0	0	0	0	2	2	0	0	0	0	0	0
1610000715472	T	EA	F82500	O1		0	0	1	2	4	0	10	0	0	0	0	0	0
1610008736423	T	EA	F82500	O1		0	0	0	0	0	1	11	0	0	0	0	0	0
SRAN TOTAL						0	0	1	2	4	1	21	0	0	0	0	0	0
1610000715472	T	EA	F82805	O1		0	0	0	0	0	0	1	0	0	0	0	0	0
1610000715472	T	EA	F82823	O1		0	0	0	3	5	0	7	0	0	0	0	0	0
1610008736423	T	EA	F82823	O1		0	0	0	2	0	0	2	0	0	0	0	0	0
SRAN TOTAL						0	0	0	5	5	0	9	0	0	0	0	0	0
1610000715472	T	EA	F83010	O1		0	0	0	2	8	0	8	0	0	0	0	0	0
1610008736423	T	EA	F83010	O1		0	0	0	5	0	2	11	1	0	0	0	0	0
SRAN TOTAL						0	0	0	7	8	2	19	1	0	0	0	0	0
1610000715472	T	EA	F83300	O1		1	0	0	1	2	0	2	0	0	0	0	0	0
1610008736423	T	EA	F83300	O1		0	0	0	0	0	0	1	0	0	0	0	0	0
SRAN TOTAL						1	0	0	1	2	0	3	0	0	0	0	0	0
1610000715472	T	EA	F84417	O1		0	0	0	0	1	0	6	0	0	0	0	0	0
1610008736423	T	EA	F84417	O1		2	0	0	0	0	1	10	0	0	0	0	0	0
SRAN TOTAL						2	0	0	0	1	1	16	0	0	0	0	0	0

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PCN: A-D104.-FF1-Q1-MFF

IM QUARTERLY WORLDWIDE ASSETS AND LEVELS REPORT

AS OF 31 MAR 87

RUN DATE 16 APR 87

FSC 1610

MANAGER 2MV

SUB GROUP MASTER NSN E R C UI SRAN TE AC CD CD

CURRENT NSN 1610000715472 T EA FB4420 01

1610000736423 T EA FB4420 01

SRAN TOTAL 4

1610000736423 T EA FB4425 01

1610000715472 T EA FB4460 01

1610000736423 T EA FB4460 01

SRAN TOTAL 8

1610000715472 T EA FB4469 01

1610000736423 T EA FB4469 01

SRAN TOTAL 0

1610000715472 T EA FB4479 01

1610000736423 T EA FB4479 01

SRAN TOTAL 0

1610000715472 T EA FB4488 01

1610000736423 T EA FB4488 01

SRAN TOTAL 1

1610000715472 T EA FB4624 01

1610000736423 T EA FB4624 01

SRAN TOTAL 0

1610000715472 T EA FB4661 01

1610000736423 T EA FB4661 01

SRAN TOTAL 0

1610000715472 T EA FB4664 01

1610000736423 T EA FB4664 01

SRAN TOTAL 0

1610000715472 T EA FB4810 01

1610000736423 T EA FB4810 01

SRAN TOTAL 0

1610000715472 T EA FB4810 01

1610000736423 T EA FB4810 01

SRAN TOTAL 0

1610000715472 T EA FB4810 01

1610000736423 T EA FB4810 01

SRAN TOTAL 0

1610000715472 T EA FB4810 01

1610000736423 T EA FB4810 01

SRAN TOTAL 0

1610000715472 T EA FB4810 01

1610000736423 T EA FB4810 01

SRAN TOTAL 0

1610000715472 T EA FB4810 01

1610000736423 T EA FB4810 01

SRAN TOTAL 0

1610000715472 T EA FB4810 01

1610000736423 T EA FB4810 01

SRAN TOTAL 0

1610000715472 T EA FB4810 01

1610000736423 T EA FB4810 01

SRAN TOTAL 0

1610000715472 T EA FB4810 01

1610000736423 T EA FB4810 01

SRAN TOTAL 0

1610000715472 T EA FB4810 01

1610000736423 T EA FB4810 01

SRAN TOTAL 0

PCN: A-0104 -FF2-02-MFF

IM QUARTERLY WORLDWIDE REQUIREMENTS-RECONCILIATION - SUPPLEMENTAL

AS OF 31 MAR 87

RUN DATE 20 APR 87

FSC 1610

MANAGER 2M2

SUB GROUP MASTER NSN	E R C	UI	SRAN	TE	AC CD	OH CD	OH REP	GEN	F-M COND	F-M RTS	INIT INST	TRAN ISSU	SHIP TO	SHIP TO	SHIP NRA	PLUS IAV	MIN IAV	I-ACT / IAV	LAST QTR ASSET	CURR QTR ASSET	COMP CURR ASSET
1610000715472	T	EA	F86383	01	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
1610008736423	T	EA	F86422	01	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
SRAN TOTAL																					
1610008736423	T	EA	F86422	01	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	F86481	01	0	0	0	0	0	0	4	1	2	0	0	0	0	0	0	0	0
1610008736423	T	EA	F86482	01	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	F86633	01	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	F86637	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610008736423	T	EA	F86656	01	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	F86712	01	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
1610008736423	T	EA	F86712	01	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SRAN TOTAL																					
SUB GROUP MASTER FSN TOTAL					5	18	0	17	17	14	0	0	0	0	0	0	8	10			
1610001796130	T	EA	F82049	0A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610001796130	T	EA	F82053	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610001796130	T	EA	F82065	0A	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610001796130	T	EA	F82500	01	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0
1610001796130	T	EA	F82823	01	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1610001796130	T	EA	F83010	01	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0
1610001796130	T	EA	F83300	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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PCN: A-D104.-FF2-Q2-MFF

IM QUARTERLY WORLDWIDE REQUIREMENTS-RECONCILIATION - SUPPLEMENTAL

AS OF 31 MAR 87

MANAGER 2M2

FSC 1610

RUN DATE 20 APR 87

SUB GROUP MASTER NSN	E R C	UI	SRAN	TE	CD	AC	OH REP GEN	OH COND	F-M COND	F-M RTS	NRTS	INIT INST ISSU	TRAN R/M	SHIP TO SAP	SHIP TO NRA	PLUS IAV	MIN IAV	I-ACT / IAV	LAST QTR ASSET	CURR QTR ASSET	COMP CURR ASSET
CURRENT NSN																					
1610000715472																					
1610008736423	T	EA	FB3010	01			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	FB3300	01			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	FB4420	01			0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	FB4460	01			0	0	0	0	4	1	0	0	0	0	0	0	0	0	0
1610008736423	T	EA	FB4460	01			0	0	0	2	2	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL							0	0	0	2	4	3	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	FB4681	01			0	0	0	0	1	2	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	FB5209	01			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610008736423	T	EA	FB5209	01			0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL							0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	FB5518	01			0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
1610008736423	T	EA	FB5518	01			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL							0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	FB6031	01			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	FB6221	01			0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
1610008736423	T	EA	FB6231	01			0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	FB6252	01			0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	FB6323	01			0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
1610008736423	T	EA	FB6323	01			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL							0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
1610008736423	T	EA	FB6353	01			0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	FB6383	01			0	0	0	0	0	2	0	0	0	0	0	0	0	0	0

PCN: A-D104 -FF2-02-MFF

## 1M QUARTERLY WORLDWIDE REQUIREMENTS-RECONCILIATION - SUPPLEMENTAL

AS OF 31 MAR 87

MANAGER 2M2

FSC 1610

RUN DATE 20 APR 87

SUB GROUP	E	AC	CD	CD	OH	F-M	F-M	INIT	TRAN	SHIP	SHIP	PLUS	MIN	I-ACT	LAST	CURR	COMP
MASTER P/N	R	CD	CD	OH	CONO	RTS	NRTS	INST	R/M	SAP	NRA	IAY	IAY	IAY	ASSET	OTR	ASSET
CURRENT NSN	C	UI	SRAN	TE	GEN	REP	GEN	REP	GEN	REP	GEN	REP	GEN	REP	GEN	REP	GEN
1610000058685	T	EA	F86501	O1	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000058685	T	EA	F86562	O1	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000058685	T	EA	F86606	O1	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000058685	T	EA	F86633	O1	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000058685	T	EA	F86637	O1	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000058685	T	EA	F86656	O1	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000058685	T	EA	F86670	O1	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000058685	T	EA	F86703	O1	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000058685	T	EA	F86712	O1	0	0	0	0	0	0	0	0	0	0	0	0	0
SUB GROUP MASTER FSN TOTAL	6	0	0	0	78	73	17	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	F82059	OA	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	F82065	OA	4	12	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	F82069	OA	1	6	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL	5	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	F82500	O1	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	F82500	O1	0	0	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	F82823	O1	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T	EA	F82823	O1	0	0	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PAGE 3



PCN: A-DIOA-FFI-QI-MFF

## IM QUARTERLY WORLDWIDE ASSETS AND LEVELS REPORT

AS OF 31 MAR 87

MANAGER 2MV

FSC 1810

RUN DATE 18 APR 87

SUB GROUP  
MASTER NSN

SERV	UNSERV	DIFM	WRM	WRM	WRM	REOSN	DOTM	TOC	DUE IN	FLOAT	SPRAM
1	0	0	0	1	0	1	2	0	0	0	0
2	0	0	0	2	2	1	6	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
80	17	4	102	187	83	477	11	0	12	0	9

CURRENT NSN C UI SRAN TE

1810000713472

T EA FB6712 01

1810008736423

T EA FD2060 0L

SUB/GRP MASTR FSN TOTAL

1810000713472

T EA FB6712 01

1810008736423

T EA FD2060 0L

SUB/GRP MASTR FSN TOTAL

1810000713472

T EA FB6712 01

1810008736423

T EA FD2060 0L

SUB/GRP MASTR FSN TOTAL

1810000713472

T EA FB6712 01

1810008736423

T EA FD2060 0L

SUB/GRP MASTR FSN TOTAL

1810000713472

T EA FB6712 01

1810008736423

T EA FD2060 0L

SUB/GRP MASTR FSN TOTAL

1810000713472

T EA FB6712 01

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SUB/GRP MASTR FSN TOTAL

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T EA FD2060 0L

SUB/GRP MASTR FSN TOTAL

1810000713472

T EA FB6712 01

1810008736423

T EA FD2060 0L

SUB/GRP MASTR FSN TOTAL

1810000713472

T EA FB6712 01

1810008736423

T EA FD2060 0L

SUB/GRP MASTR FSN TOTAL

1810000713472

T EA FB6712 01

AS OF 31 MAR 87

RUN DATE 16 APR 87

IM QUARTERLY WORLDWIDE ASSETS AND LEVELS REPORT

PCN: A-D104-FF1-01-MFF

FSC 1610

MANAGER 2MV

SUB GROUP AC

MASTER NSN CD

R CUI SRAN TE

CURRENT NSN

1610000715472

1610000715472 T EA FB6562 01

1610000736423 T EA FB6562 01

SRAN TOTAL

1610000715472 T EA FB6605 01

1610000736423 T EA FB6605 01

SRAN TOTAL

1610000715472 T EA FB6606 01

1610000736423 T EA FB6606 01

SRAN TOTAL

1610000715472 T EA FB6618 01

1610000736423 T EA FB6618 01

SRAN TOTAL

1610000715472 T EA FB6633 01

1610000736423 T EA FB6633 01

SRAN TOTAL

1610000715472 T EA FB6637 01

1610000736423 T EA FB6637 01

SRAN TOTAL

1610000715472 T EA FB6656 01

1610000736423 T EA FB6656 01

SRAN TOTAL

1610000715472 T EA FB6670 01

1610000736423 T EA FB6703 01

SRAN TOTAL

1610000715472 T EA FB6712 01

TOC BAL

DOTM BAL

REQSN OBJ

WRM BAL

DIFM BAL

UNSERV BAL

SERV BAL

WRM DEMAND LVL

FM O/H

STK LVL BAL

SPRAM

FM O/H

STK LVL BAL

SPRAM

FM O/H

STK LVL BAL

SPRAM

FM O/H

STK LVL BAL

SPRAM

FM O/H

STK LVL BAL

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STK LVL BAL

SPRAM

FM O/H

STK LVL BAL

SPRAM

FM O/H

STK LVL BAL

PCN: A-D104.-FF1-01-MFF

## IM QUARTERLY WORLDWIDE ASSETS AND LEVELS REPORT

AS OF 31 MAR 87

MANAGER 2MV

FSC 1610

RUN DATE 16 APR 87

SUB GROUP	MASTER NSN	C	UI	SRAN	TE	AC	SERV	UNSERV	DIFM	WRM	WPM	DEMAND	REQSN	DOTM	TOC	DUE IN	FLOAT	SPRAM
							BAL	BAL	BAL	BAL	LVL	LVL	OBJ	BAL	BAL	FM D/H	STK	LVL BAL
1610000715472	T EA FB6371	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000736423	T EA FB6391	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T EA FB6383	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T EA FB6391	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000736423	T EA FB6391	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T EA FB6421	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000736423	T EA FB6421	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T EA FB6422	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000736423	T EA FB6422	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T EA FB6431	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T EA FB6481	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000736423	T EA FB6481	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T EA FB6482	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000736423	T EA FB6482	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T EA FB6501	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000736423	T EA FB6501	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T EA FB6520	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000736423	T EA FB6520	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SRAN TOTAL			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1610000715472	T EA FB6530	01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Appendix I: A SAMPLE CONSULTATION WITH MARS

**Welcome to the  
 Manager's Asset Reconciliation System  
 (MARS)**

This Artificial Intelligence Expert System was developed by the Air Force Institute of Technology School of Logistics with the help of Materiel Management experts from Warner Robins Air Logistics Center.

Have we ever had the pleasure of working together before?  
(answer by typing in yes or no and then hit the carriage  
return)

```

yes
no
>> n

```

[illegible]

Hi! I'm MARS. My job is to assist you in the maintenance of asset reconciliation records. Together we can provide a complete, current, accurate and permanent record of assets in the system. I will work with you, step by step, through the AFLC Form 47. Occasionally, I will recommend specific actions to you. I can't provide advice on every problem. Sometimes you may still have to ask your supervisor. However, I can help you with most things. I'll do my very best.

[illegible]

```
when you are ready to continue, type 'c' and hit enter key.
      c
>> c
```

What I'm going to do is ask you several questions regarding the information on your Form 47 and supporting documentation. When I ask a question, answer with one of the suggested answers which follow each question then hit the carriage return.

If you are unsure how to answer a question type 'unknown' and I will give you a detailed explanation of what I am asking.

Now let's get started. When you are ready to continue, type 'c' and hit enter key.

c  
>> c

Enter the National Stock Number (subgroup master) in quotes now.

Example '4320-00-071-1745PP'.

any lower-case expression.  
>> '1234-11-654-3245BB'

Enter the Item Activity Code (IAC) in quotes now.

Example 'C8'. Answer 'unknown' for an explanation of activity code designation.

any lower-case expression.  
>> 'C4'

Enter the 'as of date' in now.

Example 30/06/87.

any lower-case expression.  
>> 30/09/87

1. All procurements in support of POS, WRSK/BLSS, OWRM, FMS stock levels. This includes all current on-order undelivered quantities.
2. ISSP.
3. Contract termination.
4. On-order PR funded.
5. Asset gains from prior cycle.
  - a. Reclamation
  - b. Modification
  - c. Depot IAVs

Caution: Do not include FMS direct cite, installs, other service MIPRs, and unfunded PRs/MIPRs.

Block 1. What is the total quantity of acquired assets from the AFLC form 318? Include the above:

If form 318 is incomplete/unavailable, then the value for Block 1 should equal total reported in SB & CR (D104) plus any verifiable losses. Check the factors printout, transaction registers, and SB & CR Reconciliation, etc.

an integer.

>> 110

total-acquired-assets = 110 (100%) because you said so.

Ok?

yes

no

>> y

Did you exclude FMS direct cite, installs, other service MIPRs, and unfunded PRs/MIPRs?

yes

no

>> y

good!

Block 2 should equal Block 1 unless:

1. The previous form 47 indicates starting position has been adjusted on a prior cycle.
2. A decision is made to adjust Block 2 based on the variance for the three, most recent, consecutive cycles.

Enter the quantity for Block 2 now. (i.e. previous qtr Block 2 qty + any variances + any asset gains)

Note: An opportunity to adjust Block 2 for Block 13 variance will be provided shortly.

an integer between 0 and 100000.  
>> 105  
starting-position = 105 (100%) because you said so.

Ok?

yes  
no  
>> y

Is the Block 2 quantity different from the Block 1 quantity?

yes  
no  
>> y

Annotate the date on the Form 47 that established Block 2.  
Example 30/06/87.

Note: If you are going to adjust for variance this quarter,  
use the current quarter date.

any lower-case expression.  
>> 31/03/87

Does block 13 of the Form 47 indicate that the item has  
experienced three consecutive cycles with positive variances  
or three consecutive cycles with minus variances?

yes  
no  
>> y

What is the smallest absolute value of the three consecutive  
positive variances or the three consecutive negative  
variances?

Example: If you had -8, -5, and -9 for your previous three  
cycles; you would enter 5 at this time.

an integer.  
>> 3

Is the variance positive  
or negative?

positive  
negative  
>> n

102 is the new starting position; explain the reason for  
adjustment in the remarks block.

Enter your remarks in quotes now.  
Example 'Block 2 adjusted for variance noted in the previous  
three cycles.'

Note: If remarks are not required, type n/a and continue.

any lower-case expression.  
>> 'Block 2 adjusted for negative variance.'

Enter the number of condemnations accumulated from the  
previous quarter now.

an integer between 0 and 100000.  
>> 2

Block 3. How many condemnations occurred this quarter?  
You could check the factors printout, D032/D033 weekly,  
12 months transaction history and SB & CR.

an integer between 0 and 100000.  
>> 2

Have you included base condemnations and depot SB & CR  
condemns? Type 'no' to go back and adjust the condemnations  
line as necessary.

yes  
no  
>> y

4 is the accumulated quantity for condemnations this quarter.



Enter the number of mock-ups accumulated from the previous quarter now.

an integer.  
>> 0

Block 3. How many mock-ups have occurred this quarter? Check the transaction register for project 441 issues to repair facility. Enter the total accumulated quantity.

an integer between 0 and 100000.  
>> 0

0 is the accumulated quantity for mockups this cycle.

Block 3. Enter the number of installations accumulated from the previous quarter now.

an integer.  
>> 1

Block 3. How many installations or shipments for spram have occurred this quarter? Check the SB & CR for installations and the transaction register for project code 428 issues as spram.

an integer between 0 and 100000.  
>> 2

3 is the accumulated quantity for installations this cycle.

Enter the number of test equipment items accumulated from the previous quarter now.

an integer.  
>> 1

Block 3. Enter the number of test equipment items accumulated from the current quarter that were issued to a repair facility for testing, check out purposes, or to fill a table of allowance requirement.

an integer between 0 and 100000.  
>> 1

2 is the accumulated quantity for test equipment this cycle.

Enter the number of shipments to FMS accumulated from the previous quarter now.

an integer.  
>> 0

Block 3 (shipments to FMS/SA). How many assets have been shipped from stock this quarter to FMS/SA customers? Check the SB & CR shipment to SAP, then deduct H coded requisitions shown in the transaction register under the FB2065 quantity.

Note: If using transaction register:  
Do not count direct shipments from contractors.  
Do not count shipments from WRM accounts.  
Do not count other services off-base storage sites.

an integer between 0 and 100000.  
>> 0

0 is the accumulated quantity for shipments to FMS this cycle.

Enter the number of NRA items accumulated from the previous quarter now.

an integer.  
>> 1

Block 3. Check the SB & CR and/or transaction registers to determine how many assets were shipped from stock this quarter to NRA. Non reporting activities are listed in AFM 67-1, vol I, part 2, chapter 1, attachment 1.

1. Include shipments to material utilization control office
2. Do not include SICA services when assets are to be returned or unserviceable exchanged for serviceable
3. Do not include DMISA items.

an integer between 0 and 100000.

>> 0

1 is the accumulated quantity for NRA this cycle.

Block 3. How many assets will not be returned to the AF spares inventory due to special project requisition? Enter the accumulated total now.

Note: An availability request should have been submitted for any special project losses.

an integer between 0 and 100000.

>> 2

Block 3. How many assets were lost to modifications this quarter? 1. Include assets modified to another configuration and not part of this subgrouping. 2. Include assets used in modification of a Next Higher Assembly. If you suspect losses, check with production management or the equipment specialist.

Enter the accumulated total now.

an integer between 0 and 100000.

>> 2

Block 3. Include the number of depot Inventory Adjustment Vouchers, reported in the SB & CR, on the Minus IAV line.

Enter the accumulated total now.

an integer between 0 and 100000.

>> 7

Block 3. Look at the transfers to the Defense Re-utilization and Marketing Office (DRMO) shown in the SBCR under items coded disposal, this number represents the number of assets which have been declared non reparable without being condemned. You should have processed a transfer document to get these assets shipped to R & M. Enter the accumulated total now.

an integer between 0 and 100000.  
>> 6

Block 3. How many asset losses have not been listed in any of the previous categories? Enter the accumulated total now. Examples: Gifts of assets to the Air Museum, items donated to State or County governments. Annotate the accumulated total of any such asset losses on the line labeled 'other' and explain in the remarks section at the bottom of the form 47.

an integer between 0 and 100000.  
>> 4

### 3. ASSET LOSSES

a. Condemnations	4
b. Mock-ups	0
c. Installations/SPRAM	3
d. Test Equipment	2
e. Shipments to FMS/SA Programs	0
f. Shipments to Non-Reporting Activities	1
g. Special Projects	2
h. Modification	2
i. Minus IAV	7
j. Transfers to DPDO	6
k. Other (explain in remarks)	4

---

TOTAL(Asset Losses) 31

If the values listed above are not to your satisfaction restart the consultation or continue and an opportunity to change the values for condemnations, FMS/SA program items, NRA items, Minus IAV will be provided later in this program. When you are ready to continue, type 'c' and hit enter key.

c  
>> c

Block 4. How many assets were gained this quarter by an inventory adjustment? Look at the SBCR and disregard base IAVs using depot IAVs only.

an integer between 0 and 100000.  
>> 8

Block 4. How many assets were gained this quarter through modification of an item, aircraft, or system? Any gain reported here should be the result of a decrease in assets on the old, unmodified NSN.

an integer between 0 and 100000.  
>> 12

Block 4. How many other gains have not been listed? Examples include, discontinued special projects and the reclamation of a Next Higher Assembly or an aircraft. Annotate any such gains on the line labeled 'other' and explain in the remarks section at the bottom of this Form 47.

an integer between 0 and 100000.  
>> 9

4. ASSET GAINS	
a. Plus IAV	8
b. Modification	12
c. Other (explain in remarks)	9

---

TOTAL(Asset Gains) 29

Remember that asset gains are non accumulative and are shown in Block 4 for the current quarter only; should not be included in block 1 or 2 of the cycle being reconciled.

100 represents your balance  
accountable assets value for block 5.

when you are ready to continue, type 'c' and hit enter key.

<sup>c</sup>  
>> c

Block 6. How many funded PRs/MIPRs are due in as of the asset cut-off date? Look at the master and subs overlay from the J041, you should have received a 339 card also. This information is also listed on the form 318.

Note: Do not include other service MIPRs/PRs or assets on contract for direct FMS shipment.

    an integer between 0 and 100000.  
>> 10

If you had funded PR/MIPR, did you include this quantity in blocks 1 and 2 ?

    yes  
    no  
>> y

Good!

Each PR should have been confirmed as funded by review of the H057 report.

What is the total quantity on order contract as of the cutoff date? Look at the overlay from the J041, should have received a 339 card, also posted on AFLC Form 318.

    an integer between 0 and 100000.  
>> 2

Information entry.

What is the total of all unfunded PRs/MIPRs? Look at J041, include PRs that were initiated without money being committed as of the asset cut off date of the computation.

You should check the H057.2LI accounting document or special ALC products, provided for this purpose, to determine if any unfunded PRs were actually committed as of the asset cut off date; if they were, they should be included in the quantity listed under 'On order PR/MIPR (funded)'.

an integer between 0 and 100000.  
>> 12

Did you include them in your on order PR/MIPR (funded) quantity?

yes  
no  
>> y

Good!

Block 6. How many assets are due in from ISSP? Look at the J041 for any projected receipts from other services, do not include projected unserviceable returns from SICA services.

an integer between 0 and 100000.  
>> 5

Block 6. How many assets are due in from reclamation? Look at the J041, D067, other applicable records and include assets reclaimed from Next Higher Assemblies, crashed or damaged aircraft, and save lists.

Enter 'why' if you need further information.

an integer between 0 and 100000.  
>> 4

Have you verified the reclaimed asset value by reviewing the following?

1. A-D067.-R41-R1-MR4.
2. AFLC Form 206 for reclamation of Next Higher Assembly.

If you enter no or unknown, the system will ask you to re-enter the number of assets due in from reclamation.

yes  
no  
>> n

Block 6. How many assets are due in from reclamation? Look at the J041, D067, other applicable records and include assets reclaimed from Next Higher Assemblies, crashed or damaged aircraft, and save lists.

Enter 'why' if you need further information.

an integer between 0 and 100000.  
>> 6

Have you verified the reclaimed asset value by reviewing the following?

1. A-D067.-R41-R1-MR4.
2. AFLC Form 206 for reclamation of Next Higher Assembly.

If you enter no or unknown, the system will ask you to re-enter the number of assets due in from reclamation.

yes  
no  
>> y

Good!

How many assets are in contract termination status but still due in? This information is advertised by the D/MM MUCO to D/MM Item Managers like yourself. You can submit DD form 1149 to obtain contract termination quantity information.

an integer between 0 and 100000.  
>> 8



How many other due-in assets are there? An example would be an item pending modification that is not a part of this subgroup. Be sure to explain in the remarks block if you have any assets in this category.

an integer between 0 and 100000.  
>> 0

6. DUE-IN ASSETS

a. On order PR/MIPR (Funded)	10
b. On order contract	2
c. Unfunded PR (Information Entry)	12
d. ISSP	5
e. Reclamation	6
f. Contract Termination	8
g. Other (explain in remarks)	0

---

TOTAL(Due-in Assets) 31

69 represents your net  
balance accountable for block 7.

when you are ready to continue, type 'c' and hit enter key.  
c  
>> c

Block 8.

What are your current assets as reported in the SB & CR  
(overlay from D104 system initial comp)?

The following entries are optional entries listed under  
block 8:

Serviceables both base and depot, include DIFM  
Unserviceables both base and depot  
Intransit serviceable  
Intransit unserviceable  
WRM serviceable  
Due-In from Overhaul (DIOH)  
Other (explain in remarks)

The total of all the entries, if entered, should be  
reflected in the initial D041 requirements computation.  
an integer between 0 and 100000.

>> 62  
Ok?  
yes  
no  
>> y

Block 9. What is the verified DOTM quantity to include any 'H' coded FMS requisitions? Note: You should verify DOTM by calling applicable base if DOTM quantity is suspect.

Reference WRALC-MMOI 57-4, Appendix 1, pg 6 for a more detailed explanation of DOTM.

an integer between 0 and 100000.  
>> 3

Ok?

yes  
no  
>> y

59 is the net SB & CR assets quantity to be entered in Block 10.

-10 is the difference value to be entered in Block 11 and represents an underage of items reported this quarter.

This is a suggested area to research in order to resolve your difference value

Have you verified the correct value for condemnations by accomplishing the following? Review of the contractor's end item report (form 413) Review of the D032/D033 weekly transaction register Contacting PMS

yes  
no  
>> n

The condemnation quantity you have computed for this reconciliation is = 4 (100%) because rule-152.

If you wish to change the value for condemnations, enter the amount of change (plus or minus) now. Example 20 or -20. If you do not wish to change the condemnations value, enter 0.

an integer.  
>> 4

8 is the adjusted  
condemnations value to be entered on the Form 47

35 is the adjusted  
total asset losses value to be entered on the Form 47

96 is the adjusted  
balance accountable assets value

65 is the adjusted  
net balance accountable value

-6 is the adjusted  
difference value for Block 11  
when you are ready to continue, type 'c' and hit enter key.

c  
>> c

Have you verified the number of shipments to FMS/SA  
programs, as reported in the SB & CR, by review of the  
D032/D033 weekly transaction register?

yes  
no  
>> y

Excellent!

Have the following items been excluded from your  
shipments to Non-Reporting-Activities:

1. shipments to other services for DMISMA repair
2. shipments to contractors for depot overhaul repair  
of programmed depot maintenance

yes  
no  
>> y

Outstanding!

Have the minus IAV quantities been verified by the base supply IM and/or review of the D032/D033 weekly transaction register?

yes  
no  
>> y

Keep up the good work!

Have the plus IAV quantities been verified by the base supply IM and/or review of the D032/D033 weekly transaction register?

yes  
no  
>> y

Good going!

Have the on-order contract quantities been verified by review of the due-in asset card (Form 339) in conjunction with a D008 12 months transaction history or the D032/D033 weekly transaction register?

yes  
no  
>> y

Great!

\*For your information only\* Block 12 is used to adjust reported assets after appropriate research is accomplished to determine the validity of the assets reported in the SB & CR. Research all available records such as inventory records, reports histories, and transaction histories. You should enter only those quantities with known causes that can be explained.

Strike any key to continue.

any lower-case expression.  
>> c

How many assets were determined, after research, to have been reported incorrectly by using activities (i.e. contractors, AF bases, etc.) ?

an integer.  
>> 1  
1 is the value to be entered in the  
the adjustments to reported assets (Block 12).

-5 is the net difference value to be entered in Block 13  
and denotes variance that cannot be explained.

-7.69231% is the percentage net difference value to be entered in Block 14. Note: IAW AFLCR 57-4, Worldwide Inventory required for the following:

1. Variance of +/- 5% equaling \$500,000 or more for buy, termination, or repair items.
2. Variance of +/- 10% equaling \$1,000,000 or more for items not computing buy, repair, or termination.

68 is the on-hand assets value to be used in the final computation (Block 15). If you cannot reconcile after research, explain in the remarks section that this quantity is the sum of net balance accountable and DOTM.  
When you are ready to continue, type 'c' and hit enter key.

c  
>> c

Appendix J: Sample Output from a MARS Consultation

ASSET RECONCILIATION INVESTMENT ITEMS

NATIONAL STOCK NUMBER 1234-11-654-3245BB  
ITEM ACTIVITY CODE C4  
AS OF DATE 30/9/87

1.	TOTAL ACQUIRED ASSETS	110
2.	STARTING POSITION (Date:) 31/3/87	102
3.	ASSET LOSSES	
	a. Condemnations	4
	b. Mock-ups	0
	c. Installations/SPRAM	3
	d. Test Equipment	2
	e. Shipments to FMS/SA Programs	0
	f. Shipments to Non-Reporting Activities	1
	g. Special Projects	2
	h. Modification	2
	i. Minus IAV	7
	j. Transfers to DPDO	6
	k. Other (explain in remarks)	4
	<hr/> TOTAL (Asset Losses)	31
4.	ASSET GAINS	
	a. Plus IAV	8
	b. Modification	12
	c. Other (explain in remarks)	9
	<hr/> TOTAL (Asset Gains)	29
5.	BALANCE ACCOUNTABLE ASSETS	100
6.	DUE-IN ASSETS	
	a. On order PR/MIPR (Funded)	10
	b. On order contract	2
	c. Unfunded PR (Information Entry)	12
	d. ISSP	5
	e. Reclamation	6
	f. Contract Termination	8
	g. Other (explain in remarks)	0
	<hr/> TOTAL (Due-in Assets)	31
7.	NET BALANCE ACCOUNTABLE	69
8.	CURRENT SB & CR ASSETS	65
9.	DOTM (Included in Block 8)	3
10.	NET SB & CR ASSETS (Block 8 - Block 9)	62
11.	DIFFERENCE (Block 7 vs Block 10)	-7
12.	ADJUSTMENT TO REPORTED ASSETS AFTER RESEARCH	2
13.	NET DIFFERENCE (Block 11 +/- Block 12)	-5
14.	PERCENTAGE OF NET DIFFERENCE (Block 13/Block 7)	-7.24638%
15.	ON HAND ASSETS USED IN COMPUTATION	72
16.	REMARKS: Block 2 adjusted for negative variance.	

Appendix K: Sample of a MARS Critique Form

MARS CRITIQUE

Please use the space below to make any comments about MARS (e.g., what you liked or did not like about the system, if it helped you, or how it might be improved).

Appendix L: Test Subject Critiques of the  
Manager's Asset Reconciliation System

TEST SUBJECT CRITIQUES OF THE  
MANAGER'S ASSET RECONCILIATION SYSTEM

In a word GREAT! MARS teaches while the IM accomplishes the task of reconciliation. Would like to have scroll back to adjust something when I need to. One point: There were two computer illiterate people (and there are many at this ALC) in the class. May I suggest that you scan your class and look for the older members

I believe it will be an excellent tool in working Form 47's once you get adjusted to it. Yes it helped me

I liked the questions listed. It reminds you to double check

It helped clarify some additives

Need more training

I think this will be very beneficial

This would help me a lot. Once I get a little more experience in D041. But overall I liked it

Questions asked clear and good. problem with correcting errors

Set up and answers were good. I didn't like the inability to roll back whenever you wanted to

Very good potential. If and when we get to use it.

With a direct interface between the SB & CR and the J041 systems, the MARS system would save us alot of time. It would be helpful if the information from the previous qtrs such as starting position and the variances in block 13 could be displayed.

I think the system will be a good asset to the IM.

I endorse the MARS concept.

I feel the MARS program will be extremely helpful to the item manager.



I like the system.

This will enhance the 47 system greatly. My hats off!!

Life saver!

A great program. Additive qty was distracting.

I like the computer doing the calculations for the IM. I would like to see the system operate with the numbers in the fields only and the procedures and other info on a help screen.

Very good program. Only change suggested would be to put most of the explanations for the different blocks under a 'help' screen. Experienced persons can eliminate most of the reading.

Great idea. Good teaching tool. We need this kind of thing in other areas. This will be of more help to the IM when the system will accumulate quantities and carry forward quantities from one quarter to another.

Being new in D041 item management, this system seemed very helpful in that it walks through each step of the 47 and explains where to obtain information in order to complete the form. I hope that it will be used in the future.

Wording needs to be improved but shows great potential.

After several training sessions would be much quicker than filling in Form. Program is good.

This provides more details than the manual procedure. This is a help.

-lack of familiarity with this program caused me to make a key punch error when I tried to speed up my entries.

-this program is user friendly and easy to pick up -- with experience it would be nice to be able to skip unused elements and go directly to the next entry element.

It is a good system and after the IM's have had more time to become more familiar, I am sure will become a valuable tool.

Recommend each block be visible on the screen so IM can view this all the time to make changes if necessary.

I think that MARS is truly helpful and I feel that the sooner it is implemented into the system, the better.

Excellent program.

Would like to have this program go into effect immediately. Can be of invaluable assistance to all IM's!

This program is helpful especially to an inexperienced IM in preparing an AFLC Form 47 and can be used by all to refresh your memory for this task. The only problem I found was an incompatibility with MARS terminology for line 12 vs terminology indicated on AFLC Form 47.

The system should really make IM's better informed and more accurate when doing form 47's.

I feel that once this product is implemented into system will tremendously enhance the reconciliation process. What I saw in this short orientation was impressive.

This will be a very, very helpful tool in D041. I enjoyed learning something that will help me in my job. Thank you.

I have only been an IM about a month, however, I thought the system was good. I did work a few 47's, and this process helped me to understand what I was really doing.

I think this system offers clear, concise questions concerning Form 47's - simple enough. It should help.

Good idea to eliminate time involved in manually working Form 47's. I enjoyed it!

I liked the extra information you could get on what to consider and not consider on arriving at info input. I had a little trouble going back to correct errors.

Very good system. Would like to do more. Very challenging structure. This is what is needed to learn how to do these things.

The questions seemed very good and thorough for the information given. The biggest problem I had was not understanding where to pick-up the information from off the sheets. I'm not a seasoned IM.

In the future this will be a great time saver.

Liked 'MARS' all right. I am a new IM and not an expert on 47's, so I got sorta lost. There needs to be more of a mechanism to change earlier entries. Other than that, it was quite user friendly.

Looks good! I like this. Will be more interesting to work the 47's this way. Should save time looking through so many regs and flipping through so many sheets if you could get the NSN info in the system.

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19. Abstract

Expert system technology appears to hold considerable promise for enhancing productivity and promoting better decision-making. The purpose of this study was to determine if an expert system application for asset reconciliation could improve inventory management procedures and potentially produce savings for the Government while alleviating manpower shortages.

The primary objective of this research was to validate and extend a previous research finding that documented a 11 percent increase in the effectiveness of inventory managers when assisted by an expert system. Research was conducted to develop an expert system for a different task and to measure the performance level of this expert system, both in terms of the effectiveness and the efficiency of item managers who were assisted by the system.

The methodological approach to the research project involved a twelve-step process that was divided into three general phases. The objective of the first phase, problem selection, was to choose a problem to be addressed by the expert system and to select the domain experts whose knowledge would be encoded into the expert system for the chosen problem. The objective of the second phase, knowledge engineering, was to extract the knowledge from the selected experts in order to create a knowledge base for the expert system. The objective of the third phase, performance evaluation, was to determine if the development of an expert system enhanced or detracted from the productivity of inventory managers using the system.

The expert system developed was titled the Manager's Asset Reconciliation System (MARS). MARS improved the overall effectiveness of item managers by 19.45 percent. There appeared to be a reduction in the efficiency of item managers assisted by the expert system. User acceptance of MARS was high and recommendations for further testing of MARS are provided.

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